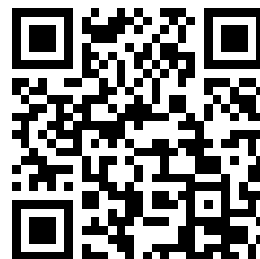
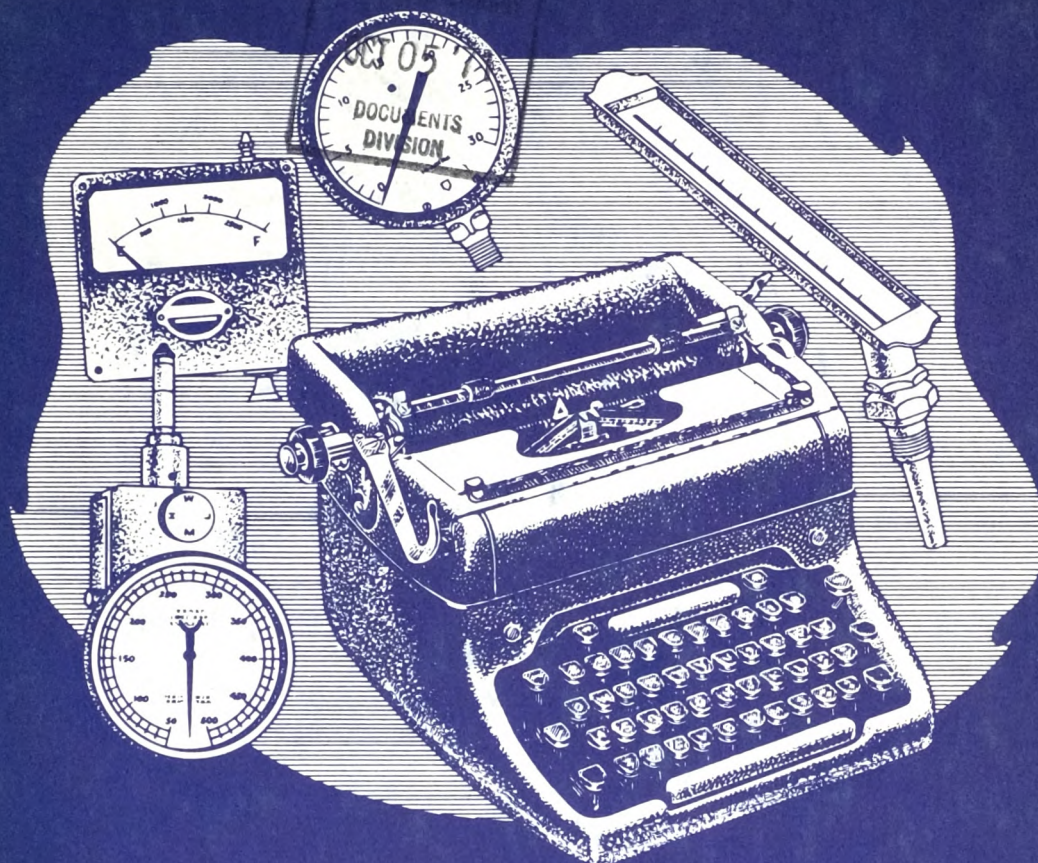

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INSTRUMENTMAN 3 & 2

BUREAU OF NAVAL PERSONNEL

RATE TRAINING MANUAL

NAVPERS 10193-C

O 208.11:In 7/2/971

PREFACE

This training manual was written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Instrumentman 3 and 2. Combined with the necessary practical experience and a thorough study of the related basic Rate Training Manuals, the information in this manual will help the reader prepare for advancement examinations.

This Rate Training Manual was prepared by the Training Publications Division, Naval Personnel Program Support Activity, Washington, D.C., for the Bureau of Naval Personnel. Information provided by numerous manufacturers and technical societies is gratefully acknowledged. Technical assistance was provided by the Service School Command, Great Lakes; the Naval Examining Center, Great Lakes; and the Naval Ship Systems Command.

First Edition 1949

Revised 1951, 1963

Stock Ordering No.
0500-069-0010

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON D.C. : 1971

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

ADVANCEMENT IN RATE

This training manual is designed to help you advance to Instrumentman Third Class and to Instrumentman Second Class. To be eligible for advancement, you must fulfill certain requirements which are explained later in the chapter.

One of the major requirements for advancement is that you possess or acquire certain qualifications (often called "quals") that have been specifically prescribed for each pay grade or rate level of your particular rating. These quals are often referred to as "standards" for advancement or as "qualification requirements" for advancement. Since the quals for each rating deal with the technical or occupational subject matter of that rating, they are often called "occupational quals," "professional quals," or "technical quals."

In addition to the occupational, professional or technical quals prescribed for each rating, there are certain military qualifications or requirements to be met. The military requirements for advancement are discussed briefly in this chapter and in detail in specific training manuals prepared to cover the military requirements for advancement.

The Instrumentman qualifications used as a guide in the preparation of this training manual are those contained in Revision B of the Manual of Qualifications for Advancement, NavPers 18068, change 6. Changes occurring after change 6 are not reflected in the text.

In this chapter, and the others that follow, you will find general and technical information which will help you in attaining the knowledge and skill required to win the Instrumentman's emblem. Start working for it now. It's worth having. Remember, however, that you cannot depend on the printed word alone to become an Instrumentman; you must supplement the information you obtain from books with actual practice and with knowledge acquired from observing experienced men at work.

Chapter 2 discusses the repair department functions, personnel, shops, and shop administration aboard tenders and repair ships. Chapters 3 and 4 present some basic principles of measurement and basic laws of Physics, as well as the international and national standards of measurement so that the Instrumentman can relate these fundamental principles to the actual measuring devices and test equipment discussed in subsequent chapters of this training manual. Chapters 5 and 6 cover the classification, construction, installation, functions, maintenance, and repair of the various types of pressure gages used on Navy ships. Temperature measuring devices such as expansion thermometers and pyrometers, used aboard ship and at shore installations, are discussed in chapter 7. Chapter 8 covers the operating principles, maintenance, repair, and calibration of tachometers. The principles, of operation, nomenclature, and functions of parts in liquid level indicators are discussed in chapter 9. Chapter 10 provides information on the operating principles and procedures for overhauling and replacing parts of flow indicators used by the Navy. Torque measuring devices are discussed in chapter 11. Chapters 12 and 13 deal with watch and clock mechanisms and maintenance of Navy timepieces. Chapter 14 provides information on repair and manufacturing processes that relate to the maintenance and repair of equipment for which the Instrumentman is responsible. Chapters 15 and 16 provide information dealing with the component parts and functions, as well as maintenance and repair actions on typewriters and other office machines, as required by the qualifications for advancement in rate.

The remainder of this chapter gives information on the enlisted rating structure, the Instrumentman rating, requirements and procedures for advancement in rating, and references that will help you both in working for advancement

and in performing your duties as an Instrumentman. This chapter includes information on how to make the best use of rate training manuals. Therefore, it is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this manual.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

THE INSTRUMENTMAN RATING

The Instrumentman rating is a general rating; there are no service ratings. Instrumentmen perform organizational and intermediate maintenance on mechanical instruments, office machines, and Navy timepieces, and implement Navy or Mechanical Instrument Repair and Calibration Shop (MIRCS) procedures.

As an Instrumentman 3 or 2, you will normally be assigned duty on a tender or a repair ship, or at a shore station. Although the size of the shop in which you work and your equipment will vary, when the shop supervisor assigns you a job, use your knowledge and skills to do the best job possible with the tools available.

As an Instrumentman 3 striker, one of your responsibilities will be to disassemble and reassemble, as well as clean and lubricate, Bourdon tube pressure gages. One of your qualifications as an Instrumentman 2 striker requires you to demonstrate the procedure for "contamination" flushing and testing of bleeder and deadened type oxygen and nitrogen, Bourdon tube gages in accordance with Military Standards 1330 (Ships) titled Cleaning and Testing of Oxygen and Nitrogen Gas Piping Systems. Regardless of your responsibilities, you must have the ability to work with your hands as well as your mind. However, if you have not had much experience working with your hands, you will gain

confidence in yourself and in your work through performance of your daily duties.

Your ability as an Instrumentman is not measured in terms of the amount of shop equipment that you can operate, but your ability is measured in terms of how well you can get the most out of the existing equipment to get the job done. Regardless of the type of shop equipment available at your duty assignment, the experienced gained will be beneficial in helping you to qualify for advancement.

General Order No. 21 states that successful leadership at all levels is based on personal example and moral responsibility. As you prepare for advancement to IM3 and then to IM2, you will find that you have increasing responsibilities for military and technical leadership. Your responsibilities for military leadership will be about the same as those of petty officers at the same rate level in other ratings, since every petty officer must be a military leader as well as a technical specialist in his own occupational field. You must be familiar with the security program, methods used by agents of foreign governments to subvert U. S. Military personnel, disciplinary action resulting from violations of security regulations, and regulations for custody, control, and accounting for classified material as well as those for transmitting Secret, Top Secret, and Confidential material. Additional information is obtained in chapter 17 of this rate training manual.

Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Operating an instrument shop and maintaining its equipment is a job of vital importance, and it's a teamwork job; it requires a special kind of leadership ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Technical leadership involves more than just giving orders. In fact, you can demonstrate some of the most important aspects of technical leadership even if you are not required to tell anyone else what to do. As an IM3 or an IM2, you demonstrate technical leadership when you follow orders exactly, when you observe safety precautions, when you accept responsibility, when you continue to increase your knowledge of the Instrumentman's job, and when you perform every detail of your work with complete integrity and reliability.

Integrity of work is really a key factor in technical leadership, and all other factors relate

to it in some way. Integrity of work is demonstrated in big ways and in little ways—the way you disassemble and reassemble chronometric tachometers, the way you perform a casualty analysis and repair pressure gages, indicating devices, or regulators, the way you calibrate and adjust instruments, using the Navy calibration or MIRCS procedures, the way you true and pin a pressure gage hairspring, the way you perform range and linearity, hysteresis, and repeatability tests, the way you replace watch stems, crowns, hands, cannon pinions, jewels, and mainsprings, and the way you prepare requisitions for tools, spare parts, and consumable supplies. When you perform every job as well as you can, and are constantly working to increase your skill and broaden your knowledge, you are demonstrating integrity of work in a practical manner. When your work has integrity, you are demonstrating technical leadership.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

But the advantages of advancing in rate are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required military and occupational training manuals.
3. Demonstrate your ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors,

NavPers 1414/1. In some cases the Record of Practical Factors may contain the old form number, NavPers 760.

4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.

5. Demonstrate your KNOWLEDGE by passing written examinations on the occupational and military qualification standards for advancement.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the most recent qualifications.

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to “sew on the crow” or “add a stripe.” The number of men in each rate and rating is controlled on a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the “final multiple” and is a combination of three types of advancement systems.

Merit rating system
Personnel testing system
Longevity, or seniority, system

The Navy’s system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

<u>Factor</u>	<u>Maximum Credit</u>
Examination score	80
Performance factor (Performance evaluation)	50

REQUIREMENTS*	E1 to E2	E2 to E3	#† E3 to E4	#E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service—or completion of	6 mos. as E-2.	6 mos. as E-3	12 mos. as E-4	24 mos. as E-5.	36 mos. as E-6. 8 years total enlisted service.	36 mos as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3.			Class B for AGC MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* All advancements require commanding officer's recommendation.

† 1 year obligated service required for E-5 and E-6; 2 years for E-7, E-8 and E-9.

Military leadership exam required for E-4 and E-5.

** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.

†† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO Advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

<u>Factor</u>	<u>Maximum Credit</u>
Length of service (years x 1)	20
Service in pay grade (years x 2)	20
Medals and awards	15
	185

All of the above information (except the examination score) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, (3) a NavPers publication called Training Publication for Advancement, NavPers 10052, and (4) applicable rate training manuals. The following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

QUALS MANUAL

The Manual of Qualifications for Advancement, NavPers 18068-B (with changes), gives the minimum occupational and military qualification standards for advancement to each pay grade within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualification standards are of two general types: (1) military qualification standards and (2) occupational qualification standards.

MILITARY STANDARDS are requirements that apply to all ratings rather than to any one particular rating. Military requirements for

advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL STANDARDS are requirements that are directly related to the work of each rating.

Both the military requirements and the occupational qualification standards are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

In most subject matter areas, you will find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find only one or the other. It is important to remember that there are some knowledge aspects to all practical factors, and some practical aspects to most knowledge factors. Therefore, even if the Quals Manual indicates that there are no knowledge factors for a given subject matter area, you may still expect to find examination questions dealing with the knowledge aspects of the practical factors listed in that subject matter area.

You are required to pass a Navywide military leadership examination for E-4 or E-5, as appropriate, before you take the occupational examinations. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates are required to pass the applicable military/leadership examination only once. Each of these examinations consists of 100 questions based on information contained in Military Requirements for Petty Officers 3 and 2, NavPers 10056 (current edition) and in other publications listed in Training Publications for Advancement, NavPers 10052 (current edition).

The Navywide occupational examination for pay grades E-4 and E-5 will contain 150 questions related to occupational areas of your rating.

If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The occupational qualifications for your rating which are covered in this training manual were current at the time the manual was printed. By the time you are studying this manual,

however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an UP-TO-DATE copy in the Quals Manual.

RECORD OF PRACTICAL FACTORS

Before you can take the servicewide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military qualifications and the occupational qualifications. The RECORD OF PRACTICAL FACTORS, mentioned earlier, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and occupational. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement, and revised forms of NavPers 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

Until completed, the NavPers 1414/1 is usually held by your division officer; after completion, it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all practical factors, the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NavPers 10052

Training Publications for Advancement, NavPers 10052 (revised), is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NavPers 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a BuPers Notice has been issued to supplement NavPers 10052 for your rating.

The required and recommended references are listed by pay grade in NavPers 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NavPers 10052, you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Class A course.

Do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military qualification standards for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NavPers 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

There are two general types of rate training manuals. RATING manuals (such as this one)

are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NavPers number. You can tell whether any particular copy of a training manual is the latest edition by checking the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061. (NavPers 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NavPers 10052, the Naval Examining Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NavPers 10052 for a given rate, the Examining Center will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military qualifications and the occupational qualifications for your rating before you study the training manual, and refer to the quals frequently as you study. Remember, you are studying the manual primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the

entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the sub-headings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use enlisted correspondence courses whenever you can. The correspondence courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an enlisted correspondence course based on the rate training manual. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy on which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rating; it is likely to be a waste of time, and may even be seriously misleading.

BUPERS PUBLICATIONS

Some of the BuPers publications that you will need to study or refer to as you prepare for advancement have already been discussed earlier in this chapter. Inasmuch as you are required to know the functions of basic mathematics (positive integers, fractions, decimals, percentage, ratio and proportion, and interpolation) and information such as the relationship of volt, ohm, and ampere in electrical circuits, you

should refer to recommended publications dealing with these subject matter areas.

Some additional BuPers publications that you may find useful are listed here.

Basic Electricity, NavPers 10086-B
Basic Handtools, NavPers 10085-A
Blueprint Reading and Sketching, NavPers 10077-B
Fireman, NavPers 10520-D
Fluid Power, NavPers 16193-A
Mathematics, Vol. 1, NavPers 10069-C
Standard First Aid Training Course, NavPers 10081-B

NAVSHIPS PUBLICATIONS

The publications issued by the Naval Ship Systems Command will be of interest to you. Although you do not need to know everything given in the publications mentioned here, you should have a general idea of where to find information in NavShips publications.

The NavShips Technical Manual is the basic doctrine publication of the Naval Ship Systems Command. Chapters which contain information of particular interest to the Instrumentman include the following:

9870 Mechanical Measuring Instruments
 9880 Damage Control (Sections I and III, Stability and Buoyancy, and Engineering Casualty Control)
 9310 Repair Parts
 9910 Workshop Equipment on Ships

The Naval Ship Systems Command Technical News is a monthly publication which contains interesting and useful articles. This magazine is particularly useful because it presents information which supplements and clarifies information given in NavShips Technical Manual and because it presents information on new developments.

MANUFACTURERS' TECHNICAL MANUALS

The manufacturers' technical manuals that are furnished with most instruments and other items of equipment are valuable sources of information on operation, maintenance, and repair. These manuals are generally available, in the shops, with each type instrument or system an Instrumentman is required to repair.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Films that may be of interest are listed in the United States Navy Film Catalog, NavAir 10-1-777, published in 1969. This catalog is now listed in the NavSup Forms and Publications Catalog, NavSup 2002. Supplements to the Film Catalog are issued periodically.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may still have sections that are useful, but it is important to note procedures that have changed. If there is any doubt, verify current procedures by looking them up in the appropriate source.

CHAPTER 2

THE REPAIR DEPARTMENT

Since you will probably be assigned to the repair department of a repair ship or tender, you should know something about repair department functions, personnel, shops, and procedures. This chapter provides an introduction to the repair department on repair ships and tenders.

REPAIR DEPARTMENT FUNCTIONS

In effect, repair ships and tenders are floating bases, capable of performing a variety of maintenance and repair services that are beyond the capabilities of the ships they serve. They are rather like small-scale Navy yards, with the same primary mission: to provide repair facilities and services to the forces afloat.

The most common type of repair ship, designated AR, provides general and specific repairs to all types of ships. Special types of repair ships have been developed for special uses; for example, the ARB is designed for the repair of battle damage and the ARG for the repair of internal combustion engines.

Each type of tender provides services for one type of ship, as indicated by the designation of the tender. The two best known types of tenders are the destroyer tender (AD) and the submarine tender (AS). Both conventional submarines and fleet ballistic missile submarines are tended by AS's; however, the organization of the repair department is somewhat different on an AS that tends fleet ballistic missile submarines than it is on an AS that tends conventional submarines.

Since repairs and services to other ships are the primary functions of all repair ships and tenders, it is obvious that the repair department on a repair ship or tender makes a direct and vital contribution to fleet support. The operating forces of the fleet depend upon the services by all personnel of the repair department.

REPAIR DEPARTMENT ORGANIZATION AND PERSONNEL

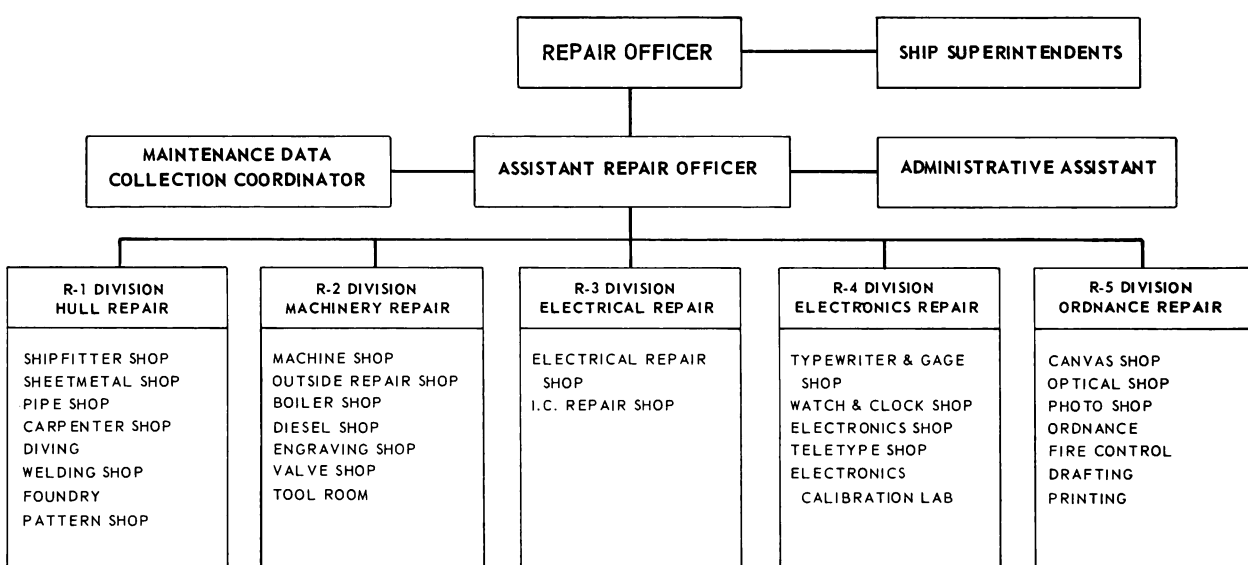
When you report aboard ship, you will need to learn the lines of authority and responsibility in the repair department. You will need to find out where your orders and assignments originate, exactly what is expected of you, and where to go for information, assistance, and advice. You can start acquiring this knowledge by studying the following material on repair department organization and personnel.

Repair department organization varies somewhat from one ship to another, as may be seen by comparison of figures 2-1 and 2-2. Figure 2-1 shows the organization of the repair department on a typical repair ship (AR); figure 2-2 shows the organization of the repair department on a fleet ballistic missile (FBM) submarine tender (AS).

In comparing these two illustrations, you will notice several differences. For one thing, the repair department on the AR includes an ordnance repair division (R-5) which is not included in the repair department of the AS. Instead, the AS has a separate weapons repair department under a weapons repair officer. Another difference is in the location of the shops you will work in. On the AR, you would probably be assigned to the R-4 division; on the AS, you would probably be assigned to the R-2 division.

The organization of the repair department on a destroyer tender (AD) is similar to that found on an AR. On an AD, however, you would probably be assigned to the R-5 (ordnance repair) division.

The duties of personnel in the repair department vary somewhat according to the type of ship. However, the following description of personnel functions will give you a general idea of the way things are in most repair departments.



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Figure 2-1.—Organization of repair department on typical repair ship (AR).

REPAIR OFFICER

On a repair ship or tender, the repair officer is head of the repair department. The repair officer is charged with the execution of all repair work and alterations assigned by competent authority to be accomplished on the ships tended or granted availabilities. The repair officer is also responsible for the accomplishment of repairs and alterations to the ship itself (tender or repair ship) that are beyond the capacity of the engineering or other departments.

Specific duties of the repair officer vary somewhat, depending upon the type of repair ship or tender. In general, however, the duties of the repair officer include the following:

1. Planning, preparing, and executing schedules covering alterations and repair work assigned to the repair department.

2. Coordinating repair capabilities, work assignments, and available personnel to ensure maximum utilization of manpower.

3. Supervising and inspecting repairs and services to ensure timely and satisfactory completion of work; providing controls for quality control.

4. Preparing records, reports, forms, and orders in connection with repair functions and duties.

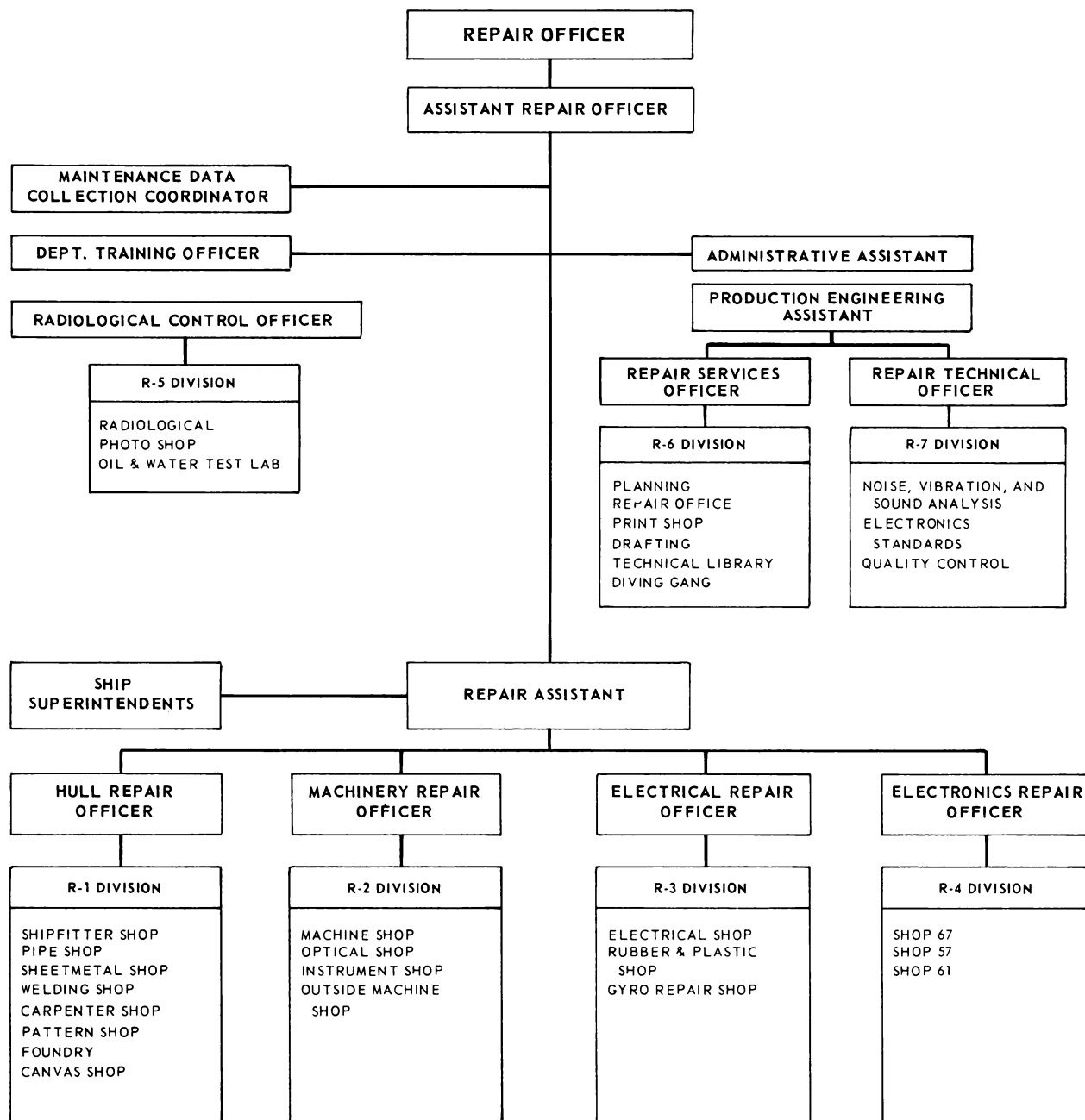
5. Ensuring proper operation of all equipment and material assigned to the repair department.

6. Ensuring strict compliance with safety precautions and security measures.

7. Reporting progress of major repairs and alterations to the commanding officer; keeping the executive officer informed; reporting promptly any inability to meet scheduled completion dates.

ASSISTANT REPAIR OFFICER

In the absence of the repair officer, the assistant repair officer (when assigned) is charged with the responsibilities of the repair officer. When the repair officer is present, the assistant repair officer performs those duties that are delegated to him by the repair officer. The assistant repair officer is usually responsible for the internal administration of the department and for the handling of repair department correspondence, records and files, reports, and reference materials. When a separate repair department training officer is not assigned, the assistant repair officer acts as training officer for the department. In addition to acting as a general office administrator, the assistant repair officer may be assigned to keep progress reports on all outstanding work, to prepare



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Figure 2-2.—Organization of repair department on fleet ballistic missile submarine tender (AS).

requisitions for special material, and to perform other specific duties.

OTHER ASSISTANTS

In addition to the assistant repair officer, there are usually several other officers who

assist the repair officer in the performance of repair department functions. These may include a production engineering assistant, a repair assistant, a radiological control officer, a department training officer, and an administrative assistant.

DIVISION OFFICERS

Each division within the repair department is under a division officer. The division officer may be a commissioned officer, a warrant officer, or a petty officer. The duties of the division officer vary, of course, according to the nature of the work done in the division.

ENLISTED PERSONNEL

As an Instrumentman assigned to the repair department of a repair ship or tender, you will work with men in a number of other ratings. It will be very much to your advantage to learn who these people are and what kind of work they do. Ratings that are often assigned to the repair department include (but are not limited to) the following: Opticalmen, Electronics Technicians, Radiomen, Fire Control Technicians, Gunner's Mates, Draftsmen, Lithographers, Shipfitters, Damage Controlmen, Molders, Patternmakers, Machinery Repairmen, Machinist's Mates, Boilermen, Boilermakers, Enginemen, Electrician's Mates, and I. C. Electricians.

You can get some idea of the work done by men of these ratings by looking through the Manual of Qualifications for Advancement, NavPers 18068 (revised). You can also learn about the work of these ratings by observing how the work is handled in the repair department. In handling repair work, it is often necessary for two or more shops (and two or more ratings) to cooperate in order to complete corrective maintenance actions.

REPAIR DEPARTMENT SHOPS

Each shop in the repair department is assigned to one of the divisions. As an Instrumentman, you will be concerned primarily with instrument repair shops. However, you will find it very useful to learn as much as you can about the other shops. After you have gotten acquainted with personnel in your own shop and have learned to find your way around your own working spaces, make an effort to find out something about the other shops in the department. Find out where each shop is located, what kind of work is done in each shop, and what administrative procedures are necessary when one shop must call on the services of another for assistance in completing corrective maintenance actions.

SHOP LAYOUT

Shop layout and arrangement vary somewhat from one ship to another, depending upon the

space available, the nature and amount of equipment provided, and the services that must be provided by the ship. The following discussion is intended to give a general picture of shop arrangements on AR, AS, and AD type ships; when you go aboard ship, you may very well find that the actual arrangement differs somewhat from the arrangements described here.

Mechanical Instrument Repair and Calibration Shop (MIRCS)

The recent development of a Mechanical Instrument Repair and Calibration Shop (MIRCS) for installation on AR, AS, and AD type ships is of great significance to all Instrumentmen. MIRCS installations will eventually be installed on all tenders and repair ships, except FBM submarine tenders. MIRCS training facilities have also been established at the Instrumentmen School, Class A, at Great Lakes. All personnel assigned to work in MIRCS installations are in the Instrumentman career pattern.

The basic purpose of the MIRCS installation is to improve instrument maintenance throughout the fleet by providing centralized instrument shops capable of calibrating and repairing fleet mechanical and electromechanical instruments to standards set forth by the Naval Ordnance Systems Command, the Naval Ship Systems Command, the Naval Air Systems Command, and the Navy Type I Standards Laboratories. (Navy Standards Laboratories are discussed in chapter 4 of this training manual.)

In general, a MIRCS facility provides the capabilities of pressure calibration (vacuum to 10,000 psi), temperature calibration (-40° F to 1000° F), flow meter calibration (to 100 gallons per minute for JP-5 and diesel oil flow meters and to 20 gallons per minute for water flow meters), tachometer calibration (to 10,000 revolutions per minute), and torque calibration (from 10 ounce-inches to 1000 pound-feet). The MIRCS installation also provides facilities for cleaning and repairing instruments and for making functional tests of automatic control components.

MIRCS installations are highly standardized as to design, arrangement, and equipment. Each MIRCS is centrally located with respect to the most commonly used shops. The general arrangement of a MIRCS installation is shown in figure 2-3. Details of the arrangement may vary slightly, depending upon the shape of the spaces available for the installation.

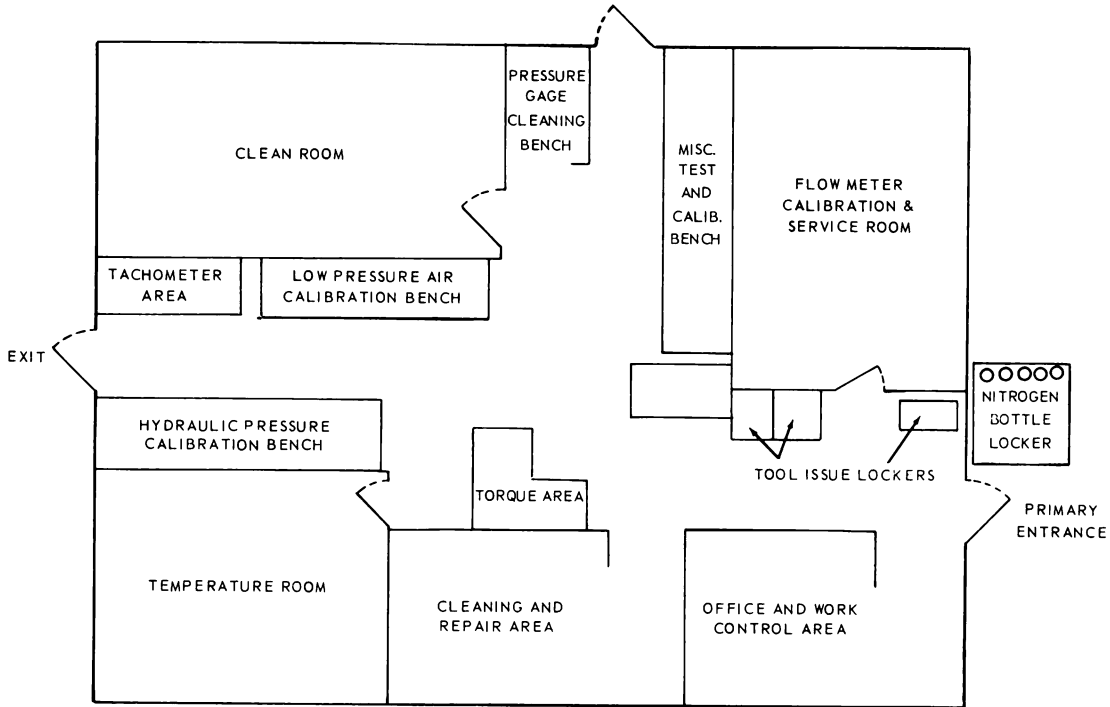


Figure 2-3.—General arrangement of space in Mechanical Instrument Repair and Calibration Shop (MIRCS).

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As may be seen, the shop includes a pressure gage cleaning bench, a "clean" room, a low pressure air calibration bench, a tachometer area, a hydraulic pressure calibration bench, a temperature room, a cleaning and repair area, a torque area, a miscellaneous test and calibration bench, a tool issue room (or tool issue lockers), an office and work control area, and (on AR's only) a flow meter calibration and service room. Appropriate equipment is provided in each space for the work to be done there. Workbenches, small parts cabinets, bookshelves, desks, chairs, and other furniture are provided throughout as required. The various MIRCS areas are described briefly in the following paragraphs, just to give you a general idea of the arrangement. The test and calibration equipment itself is discussed in appropriate chapters later in this training manual.

A PRESSURE GAGE PURGING SYSTEM is located in the cleaning and repair area. Gages that must be calibrated in the clean room are cleaned internally on the purging system and then taken immediately to the "clean" room.

The separately enclosed CLEAN ROOM (also called the OXYGEN CLEAN ROOM) is provided for the exclusive control of gages that must be "clean" for oxygen service and gages for nuclear systems, where extreme cleanliness is also of vital importance. The term "clean" is used to describe any instrument, fitting, or system that is free of oil, grease, and other organic matter and free of any loose scale, rust, grit, filings, and other foreign material. The clean room is arranged to permit the safe use and handling of high pressure nitrogen and air. It is isolated so that extremely high standards of cleanliness may be maintained. Unauthorized persons are not permitted to enter the clean room.

Equipment installed in the clean room includes test stands; a master gage panel for low and medium pressure nitrogen (oxygen clean); a master gage panel for high pressure nitrogen (oxygen clean); a nitrogen pump assembly; and a variety of workbenches, small parts cabinets, and other furniture. Nitrogen is provided by nitrogen cylinders, unless the ship has an

onboard nitrogen system that produces clean, dry water-pumped nitrogen. Figure 2-4 shows some of the test stands and master gage panels installed in the clean room.

The LOW PRESSURE AIR CALIBRATION BENCH, is shown in figure 2-5, includes a master gage panel, a test stand, a vacuum chamber and a vacuum pump, two banks of U-tube manometers (or, on AS's, one bank of U-tube manometers and a bulkhead-type aneroid barometer). On AR's and AD's, one bank of manometers goes to 50 inches of water and the other to 50 inches of mercury. Mercury shall NOT be permitted on AS's (discussed in chapter 5), so the aneroid barometer is used instead.

The TACHOMETER AREA includes a self-contained bench-type tachometer calibrator

capable of calibrating mechanical and electrical tachometers up to 10,000 revolutions per minute (rpm).

The HYDRAULIC PRESSURE GAGE CALIBRATION BENCH provides facilities for the testing and calibration of most gages. The master gage panel system is charged with distilled water. (Deadweight testers are also provided but are used only as shop reference standards for calibrating the panel gages.) The hydraulic pressure calibration bench is shown in figure 2-6.

The TEMPERATURE ROOM includes facilities for the calibration of temperature measuring devices in the high, medium, and low ranges. Liquid-in-glass, bimetallic, and distant reading type thermometers most common to shipboard

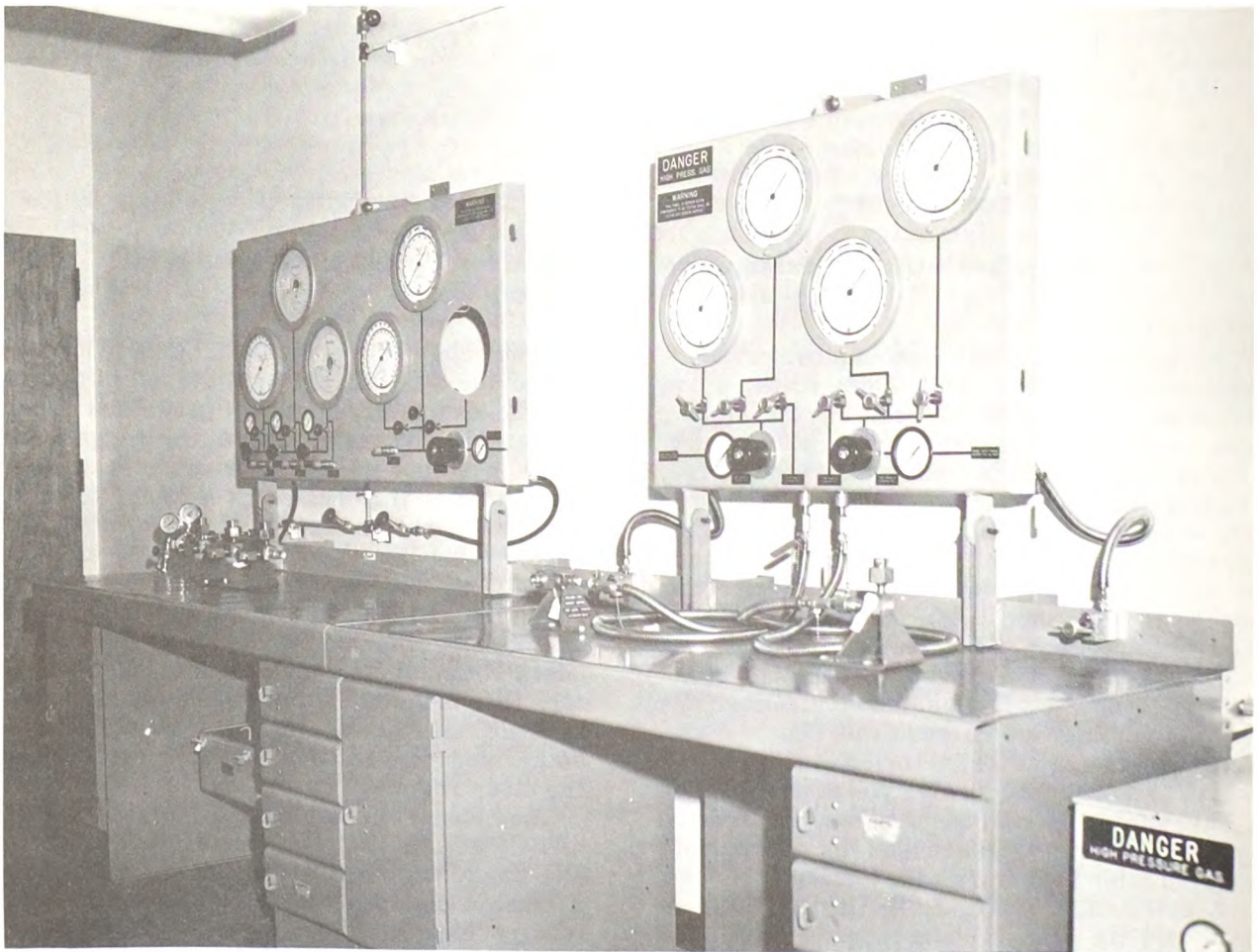


Figure 2-4.—“Clean” room in MIRCS installation.

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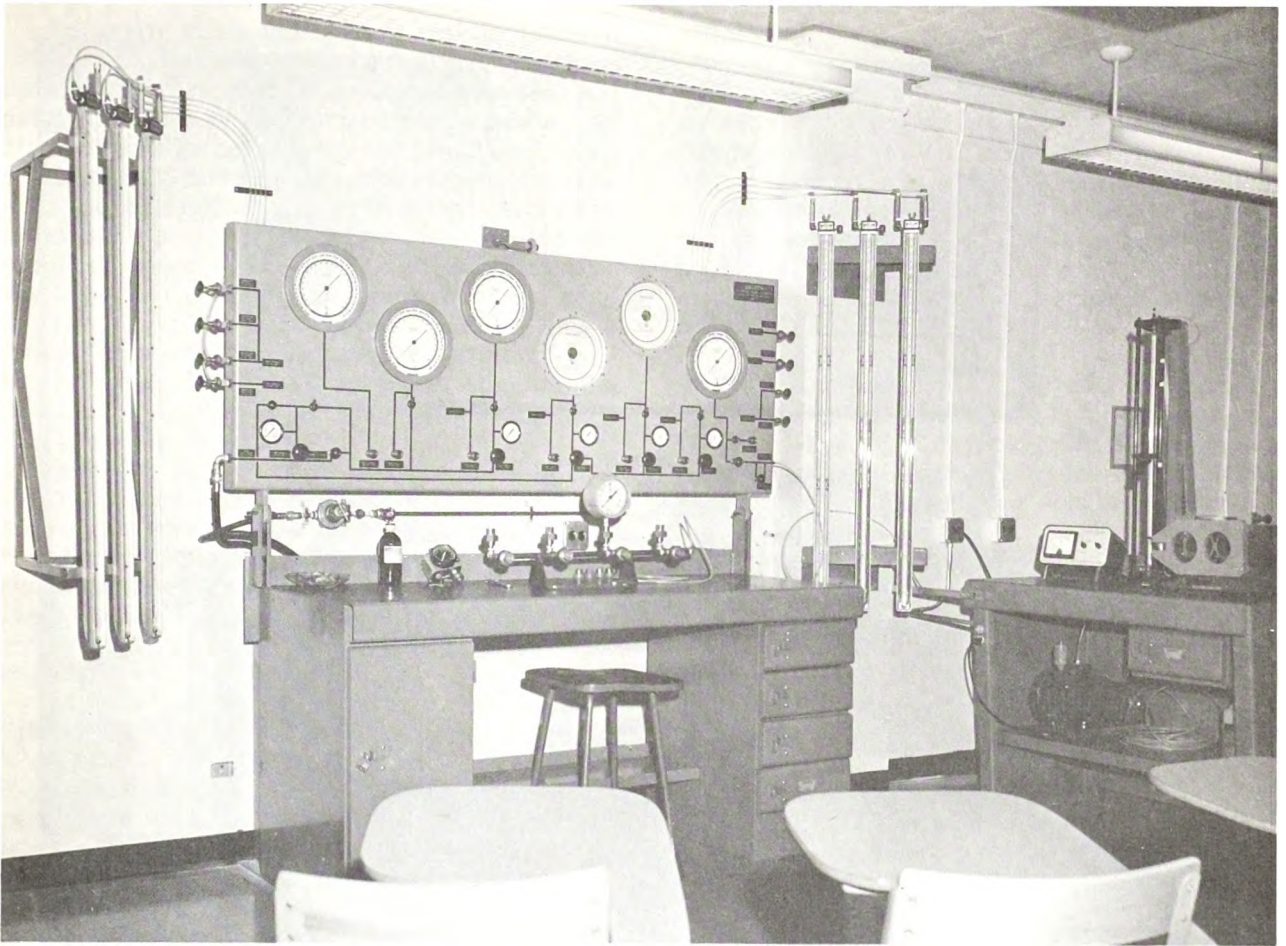


Figure 2-5.—Low pressure air calibration bench in MIRCS installation.

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can be calibrated in this room. The high, medium, and low range temperature baths comprise the primary equipment for the calibration of thermometers.

The bath units provide the calibration temperatures by heating or cooling the bath media as appropriate. A molten salt is used in the high temperature bath while certain silicone liquids are employed in the medium and low temperature baths. The temperature room also includes appropriate workbenches and other furniture.

The CLEANING AND REPAIR AREA includes ultrasonic cleaners, a sink, a grinder, a table-mounted drill press, a stowage locker, small parts cabinets, workbenches, and other furniture. It does NOT include equipment for calibra-

tion since calibration is performed at the appropriate calibration area.

The TORQUE AREA provides equipment and working space for the calibration of torque indicators.

The MISCELLANEOUS TEST AND CALIBRATION BENCH provides space and equipment for testing and calibrating master gages by means of four deadweight gage testers. The low pressure pneumatic deadweight tester, with a range of 0.5 to 30 psi, is a floating ball type unit. The medium pressure deadweight tester, with a range of 5 to 500 psi, is a bifluid unit in which water is used to transmit pressure to the gage under test and oil is used to develop pressure in the piston-and-cylinder chamber. One high pressure deadweight tester, with a range of

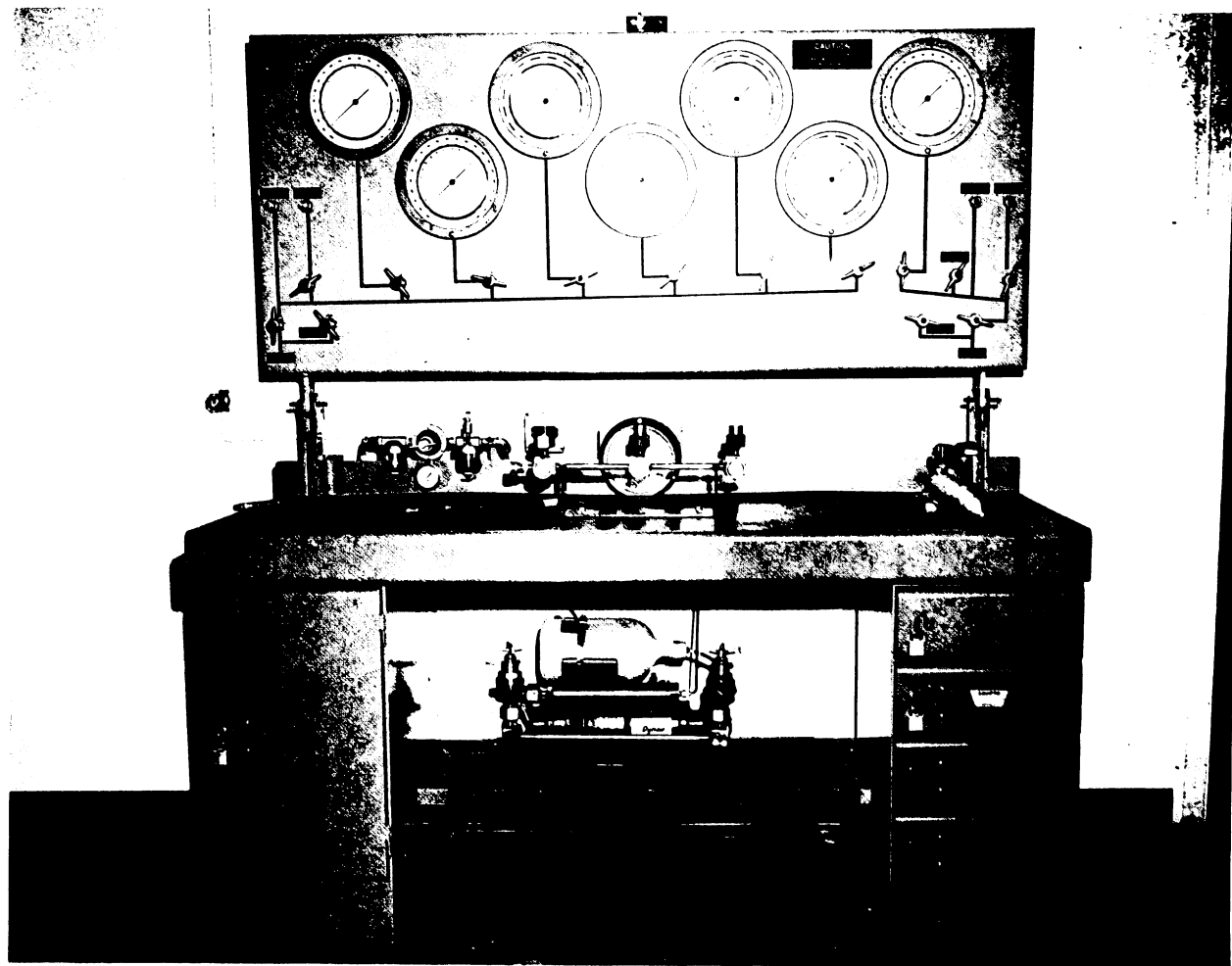


Figure 2-6.—Hydraulic pressure calibration bench in MIRCS installation.

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5 to 10,000 psi, operates with distilled water; the other high pressure tester uses hydraulic oil.

On submarine tenders (AS's) only, a PRESSURE CHAMBER is included as part of the miscellaneous test and calibration bench. The pressure chamber is a cylindrically shaped bench-mounted chamber designed for gas pressures up to 1000 psi and vacuums to 29 inches of mercury. The pressure chamber is used for pressurizing caisson and other environmental types of elastic element gages.

The FLOW METER CALIBRATION AND SERVICE ROOM is found only on repair ships (AR's). This room provides space for calibrating and servicing flow meters used in water, diesel

oil, and JP-5 systems. Equipment provided in the flow meter calibration and service room includes a flow meter cleaning tank assembly, a flow meter calibration stand, a monorail with chain hoist, and appropriate workbenches.

The TOOL ISSUE ROOM provides an area for tool issue and storage. Where space does not permit a separate tool issue room, several lockers are conveniently located and designated as tool issue lockers.

The OFFICE AND WORK CONTROL AREA contains file cabinets, stowage lockers, a desk, bookshelves, a bulletin board, and other necessary furniture.

Other IM Shops

On repair ships and tenders that do not have MIRCS installations, you will find shops in which instruments are tested, repaired, cleaned, and calibrated. These instrument shops are not as standardized in their arrangement and equipment as the MIRCS installations, and they do not provide for the high level of calibration outlined in the MIRCS program. However, they do provide facilities for a considerable amount of instrument work. On some ships the instrument shop is in a separate compartment. On other ships, the instrument shop is combined with the typewriter shop. As previously noted, the division in which the instrument shop is located varies from one ship to another.

Separate shops are provided on some ships for watch and clock repair and for typewriter repair. However, these shops may be combined with the instrument shop. In fact, you will sometimes find the instrument shop, the optical shop, the watch and clock repair shop, and the typewriter repair shop all located in the same compartment.

SHOP ADMINISTRATION

As you advance, you will have increasing responsibilities in connection with shop administration. Although an IM3 or an IM2 is not normally assigned the complete responsibility for running a shop, you may at times be called upon to act as shop supervisor and perhaps even as division duty petty officer. You will therefore find it helpful to have some knowledge of the procedures that make for a smooth flow of work through the shop. Also, it should be noted that several requirements for advancement to IM2 require a knowledge of shop procedures, records, reports, and other administrative details.

If you are assigned to act as shop supervisor, you will be responsible for:

1. Planning, scheduling, and checking the progress of shop work requests.
2. Expediting and inspecting all shop work and ensuring that all work is done correctly.
3. Seeing that all existing orders, instructions, and safety precautions are followed.
4. Maintaining order and discipline in the shop.
5. Signing receipts for all special custody tools and equipment issued to the shop.

6. Maintaining the required records and making inventories, as required by your division officer.

7. Approving or disapproving special requests of shop personnel and explaining your reasons for approval or disapproval to the division officer at the time the requests are turned over to him.

8. Inspecting the shop periodically throughout the working day and at the end of working hours to make sure that everything is clean and shipshape and that fire and accident hazards do not exist.

Shop administration requires a clear understanding of the functions and basic objectives of the shop. The shops on repair ships and tenders exist to provide services to the fleet, and all administrative procedures should contribute to this end. Good administration of a shop leads to accurate, rapid, and efficient handling of repair work. Poor administration causes confusion, delay, waste of time and materials, entanglement in unnecessary paperwork, and general inefficiency.

The following sections provide a brief introduction to certain important aspects of shop administration.

Shop Requisitioning Procedures

The supply officer is responsible for maintaining adequate stocks of repair parts and other materials. However, repair department personnel must keep the supply officer informed as to the desired high and low stocking levels for repair parts and other materials used by the repair department.

The user of repair parts, consumable supplies, and other materials must requisition the needed materials. Before you can requisition anything, you must be able to identify the material. This is not always so simple as it might sound. Let's take a look at some of the things you may need to know in order to identify the materials you need.

The Federal Catalog System currently in use throughout the Department of Defense and the civilian agencies of the Government require that only one identification number be assigned to a specific item of equipment used by and carried under centralized inventory control of any civilian or military agency of the Federal Government. The Federal Catalog System names, describes, classifies, and numbers all

items and publishes catalogs and stock and identification lists.

The Federal Stock Number (FSN) is the key to material identification. Federal Stock Numbers for an enormous number of items are given in Allowance Parts Lists (APL's), Allowance Equipage Lists (AEL's), and other lists issued by Navy commands, bureaus, or offices. Federal Stock Numbers are also given in some manufacturers' technical manuals furnished to the Navy under contract with the equipment. You will also find Federal Stock Numbers given on some blueprints, standard drawings, and similar sources. If you can find a Federal Stock Number for an item you need, you should not have any trouble requisitioning the item.

But what if you can't find a Federal Stock Number? As a second choice, see if you can find an old Standard Navy Stock Number. If the old number is available, supply personnel may be able to help you find the new Federal Stock Number.

Whenever you have difficulty in identifying a material or item that is needed, work closely with the supply department personnel who are actually responsible for identifying and requisitioning material. You have the technical knowledge, and you know what you need. But the supply personnel are familiar with many identification publications and can usually help you identify the item—provided, of course, that you are able to give them enough standard identifying information so that they will know where to start looking.

When you submit a requisition for any item, you are starting a long sequence of events that involves a great many people and a great many actions such as procurement, movement of material, and maintenance of stock records. If your identification of the item is correct, and if you fill out the requisition accurately and completely, everything should flow smoothly and you should receive the item you order. If your identification is faulty, or if your requisition is not properly filled out, you can start a long sequence of confusion that can waste time all the way along the line. And chances are you won't get the item you need.

Since the procedures for requisitioning material may vary somewhat from one ship to another, depending upon a number of factors, it is essential that you follow the procedures in use on your own ship.

Many requests for material are submitted on the Single Line Item Consumption/Management Document (Manual), NavSup 1250. This

form was developed to meet two needs: (1) the improvement of stock control procedures, and (2) the reporting of consumption under the Maintenance Data Collection System (MDCS) of the 3-M System. The department that needs the material may partially prepare NavSup 1250 or the form may be completely prepared by supply personnel, depending upon the procedures in effect on your ship. In either case, of course, the department that needs the material must provide certain information.

When you need a repair part for which no Federal Stock Number can be located, the part must be ordered with the manufacturer's part number or reference number, together with the catalog number, as identification. In this event, it is necessary to submit both the NavSup 1250 and an additional form known as NavSup 302.

A procedure known as MILSTRIP (Military Standard Requisitioning and Issue Procedure) has been developed to permit automatic processing of requisitions. Much of the information that formerly had to be written out in detail is now converted to codes that provide a common language for all of the Armed Forces and the General Services Administration. On ships that have electronic data processing equipment, MILSTRIP requisitions are submitted on DD Form 1348m; on other ships, these requisitions are submitted on DD Form 1348. As a general rule, you will not be directly involved with these forms, since the NavSup 1250 is the source of information for the preparation of DD Form 1348m and DD Form 1348.

When a ship is in port and in urgent need of certain repair parts that are available locally, a bearer or walk-through requisition is sometimes used. This type of requisition is prepared by supply personnel; the ship's representative then takes it to the supply activity, walks it through the processing steps, and receives the material.

Although shop personnel do not have the overall responsibility for the shipboard stowage of materials and supplies, they do have certain responsibilities in connection with handling materials after they have been requisitioned. All materials (including repair parts) should be properly identified up to the moment at which they are actually used. Many materials require special handling and stowage. For example, some materials must be protected from rust and corrosion; some must be protected from vibration; and some must be protected from high temperatures. Some materials, such as

cleaning fluids, gas cylinders, and paints, must be stowed in accordance with special safety precautions.

Shop Records and Reports

Running any kind of a shop requires a certain amount of paperwork. Records, reports, work requests, inventories, and work progress forms and charts must be used and processed as required on your ship. Some (but not all) shop records and reports are tied in with the 3-M System. Standard forms and blanks are provided for keeping some of the required records and for making certain supply transactions.

The WORK REQUEST, OPNAV 4700-2C, is one of the basic documents you will see and use in the repair department. The work request is part of the 3-M System, and is mentioned at this point only to note that it is one of the basic forms used for recording and reporting shop work.

Although the terms "work request" and "job order" are sometimes used interchangeably, this is not technically correct. In the past, the term work request referred only to a request made up by the operating ship and forwarded through proper channels to the repair activity; as soon as the work request was approved by the repair activity, it was called a job order. Now, however, the term work request is used both for the initial request from the operating ship and for the request after it has been accepted by the repair activity. In other words, there are no more job orders—only work requests. After a work request has been accepted by a repair activity, it is used for workload planning, estimating, scheduling, and recording the completion of shop work.

DAILY PROGRESS REPORTS are generally submitted on OPNAV 4700-2F (Work Supplement Card) to the division officer at the end of each work day, for each work request. This information is reproduced on the PRODUCTION REPORT (PR-1) daily; it is also reproduced on the MAINTENANCE CONTROL REPORT (MCR 1) twice a week, usually on Tuesday and Thursday. These reports are used by the repair officer, the division officer, and the shop supervisor. The reports can be of great value to the repair officer in estimating the workload, the utilization of personnel, and the actual progress being made.

Work Supplement Cards and Maintenance Control Reports are part of the 3-M System.

In some shops, a more descriptive type of WORK PROGRESS REPORT may be required, in addition to the 3-M System progress reports just mentioned. If your shop maintains a descriptive type of work progress log, keep it up in accordance with local requirements.

STOCK RECORD CARDS, NavSup 766, should be used for keeping a running inventory of materials received and expended and for keeping track of portable equipment. The inventory information should include the date material is received, the date expended, the amount expended, and similar details. To facilitate the preparation of stub requisitions, you may also want to include such information as the quantities of the materials listed on the ship's allowance, the location of the spaces where the material is stowed, the stock numbers, and the correct nomenclature for each material item. The equipment information should include a list of all portable tools assigned to the shop and should indicate the location of the tools. Are they in the shop? In a toolroom? In a storeroom? Assigned to an individual? The information on equipment should include adequate identification of each tool, such as make, model, serial number, and so forth. This information must be kept up to date. Both the inventory of materials and the equipment record can be of very great help when you conduct periodic inventories, but records of this type are utterly worthless unless they are faithfully maintained.

Additional records and reports may be required in connection with the work done in certain shops. For example, locally prepared forms called CASUALTY ANALYSIS INSPECTION SHEETS are often filled out when equipment is being inspected prior to repair. These sheets are used as a guide in determining whether an item should be surveyed or whether it is economically feasible to repair it. As a rough guide, the total cost of repair should not exceed 50 percent of the cost of the item. For example, you may be allowed about 50 percent of the cost of an item for a new adding machine. However, for a machine 10 years old you may be allowed approximately 10 percent of the original cost of the item. (NOTE: An item 1 year old is considered to be comparatively new.)

CHAPTER 3

PRINCIPLES OF MEASUREMENT

As an Instrumentman, you will be required to test, maintain, repair, and recalibrate pressure gages, temperature indicators, tachometers, liquid level indicators, flow meters, and other kinds of measuring devices.

To perform these duties, you will need both practical skills and theoretical knowledge. The practical aspects of instrument maintenance and repair, as well as the details of instrument construction, are discussed in other chapters of this training manual. This chapter deals with basic principles of measurement and with certain basic concepts in the field of physics. Most of the information given in this chapter, which has to do with theory rather than with practical skills, applies to more than one type of measuring device.

Why do you need this theoretical knowledge? First of all, you can't very well test, maintain, repair, and recalibrate instruments if you don't know how they work. And second, you can't really understand how the instruments work without considering the basic principles discussed.

WHAT IS MEASUREMENT?

A good way to start this discussion is by asking the question: What is measurement? By the time you have finished studying the chapter, you may decide that the question is not so simple as it sounds. As an introduction, let's look at a few basic ideas concerning the nature of measurement.

Measurement provides answers to an almost endless list of questions such as HOW MANY? HOW FAR? HOW HIGH? HOW MUCH? HOW DEEP? HOW HEAVY? HOW FAST? The only way we can get this information is by taking readings on various kinds of instruments and then interpreting the readings. Before proceeding, it should be noted that measurement is the

result of a quantitative comparison between a predefined standard and an unknown magnitude.

The measurement of energy levels is the first step toward the control of energy exchanges. Without accurate measurement we cannot have accurate control of any action or process. Throughout any naval ship you will find pressure gages, thermometers, flow indicators, tachometers, and many other measuring devices. These instruments are installed because someone needs to know something about energy levels in order to control some important aspect of the ship's operation—the running of the propulsion plant, the firing of weapons, or the provision of vital services.

In order to understand measurement, then, we will find it necessary to understand certain things about the nature of energy, the ways in which energy exchanges take place, and what is meant by energy levels.

Measuring instruments are usually designed to give numerical values, but these numerical values are not measurements until some UNIT has been stated. Numbers by themselves tell you HOW MANY, but they don't tell you what it is you have this many of. If someone owed you five dollars but paid you only five cents, it would be clear that the unit of measure should have been stated for this particular transaction. If a pressure gage pointer indicates 100, it is important to know whether the pressure is 100 pounds per square foot, 100 pounds per square inch, or 100 grams per square centimeter. If someone asks you the temperature, you may say "82" without giving any unit; but this is possible only because you and the other person both know you are using the same unit (the degree) on the same scale (probably Fahrenheit).

Many units of measure can be related in certain definite ways. Linking these related units together gives us SYSTEMS of measurement. Using these systems, we can develop still other

units for measuring still other things. For example, using the mile as a simple unit of distance and the hour as a simple unit of time, we can develop a unit "miles per hour" to indicate how fast we are going.

The very existence of units and systems of measurement implies the need for precise and uniform STANDARDS. When two people are talking about lengths or distances, they need to be sure that each inch or foot or yard or centimeter is of a certain STANDARD length. When they are talking about weight, they need to be sure that each pound or ounce or gram is of a certain STANDARD weight. If there were no standard inches or ounces, any discussion involving these units would be meaningless.

Measurement is COMPARISON—that is, comparison of a standard with the thing that is to be measured. Sometimes the comparison is quite direct and obvious, as when you compare the length of a yardstick or ruler with the length of some object you want to measure. But most measurement, which you will come in contact with, is indirect, rather than direct; most comparisons, however, are consequently not quite so obvious.

What do we mean when we say that most measurement is indirect? First, consider a mercury thermometer. We look at the thermometer and see that the mercury column stands at a certain height. From the height of the column, we infer that the temperature is a certain number of degrees on whatever scale we are using. Have we "measured" temperature? Not directly. What we have measured is the height of a mercury column—or, in other words, we observe the EFFECT of temperature upon the volume of a contained quantity of mercury. When the temperature changes, we observe what happens to the mercury column and interpret the change to mean that a corresponding change has occurred in the temperature. This measurement is indirect rather than direct.

Or consider a pressure gage. Does the position of a pointer on a gage face really "measure" pressure? Not directly. What we are measuring is the EFFECT of pressure upon the movement of a pressure element. When the movement of the pressure element is transmitted through various linkages, the pointer is moved to a certain position on an appropriately calibrated dial. The position of the pointer is thus a more or less direct measure of the DISTANCE through which the pressure element

has been moved. The measurement of pressure is indirect, rather than direct, since it is inferred from the measurement of distance. We are so accustomed to interpreting indirect measurements that we usually do not realize the extent to which we actually measure one thing and say we have measured something else.

There are several reasons why no measurement can ever be absolutely perfect. One reason is that the measuring devices may affect the variables being measured. This effect is usually very slight, but when it does exist it prevents perfect measurement. Another reason is that our instruments of measurement cannot be perfect. Even the most precise gage is subject to a certain amount of error. Another reason for errors of measurement is that our ability to read or interpret the measuring devices is less than perfect.

There are ways to compensate for errors of measurement. New types of instruments that are more precise than the old ones can be developed. New scales can be devised to enable one to read with greater accuracy. The precision of adjustments and calibrations can be increased. By applying certain mathematical correction factors, a higher degree of accuracy can be obtained. However, we can never make measurements completely free of error.

The need for greater accuracy is constantly increasing. Why do we need such great accuracy? Just look around you at the weapons and machinery on your own ship. Modern naval weapons and machinery could not be manufactured without an enormous number of very precise and accurate measurements. The more we advance in science and technology, the more dependent we become upon precision in measurement.

MEASUREMENT VARIABLES

One of the primary reasons why instrumentation is necessary is that things keep changing. If the temperature remained constant, who would need a thermometer? If the atmospheric pressure never varied, who would need a barometer? If time stood still, who would need a clock?

But things do change. Temperatures rise and fall, pressures increase and decrease, and time marches on. So we use instrumentation to observe and keep track of a great many quantities, conditions, or characteristics, called VARIABLES. If the variable is something we are trying

to control, we call it a **CONTROLLED VARIABLE**. If the variable is something we are using to control the value of the controlled variable, we call it the **MANIPULATED VARIABLE**. Many processes have more than one controlled variable and/or more than one manipulated variable. In many applications, it is necessary to measure both controlled and manipulated variables. Almost any measurement variable may be either a controlled variable or a manipulated variable; it all depends upon the particular application.

You will come across many other measurement variables as you work with different kinds of measuring instruments.

MASS is the fundamental quantity variable and is sometimes regarded as a quantity variable. The relationship between mass and weight is discussed in more detail in the section of this chapter that deals with systems and units of measurement.

FORCE, **PRESSURE**, and **TORQUE** are three closely related variables. **FORCE** may be defined as anything that tends to produce, prevent, or modify the motion or the position of a body or a substance. **PRESSURE** is defined as **FORCE PER UNIT AREA**. When force is the measurement variable, it is the **TOTAL** force that is measured; when pressure is the variable, only the force exerted upon an area of specified size is measured. "Unit area" may be a square inch, a square yard, a square centimeter, or any other convenient unit of area; the important thing to remember is that the size of the unit area must be specified. **TORQUE** is a force variable that has to do with the force applied in order to produce rotational motion.

RATE VARIABLES are those that relate to the rate at which a body or a substance moves toward or away from a specified point. Rate variables include speed, velocity, acceleration, and flow. Detailed information concerning these rate variables can be found in physics, and engineering textbooks and handbooks.

FLOW is a measure of the amount of a substance that flows past a specified point within a specified time. The flow may be measured as unit volume per unit time, unit weight per unit time, or unit mass per unit time.

FREQUENCY refers to the number of times some condition occurs within a specified time. For example, the frequency of a sound or the frequency of a light is the number of sound waves or light waves, respectively, that pass a given point in a given time.

LEVEL refers to the height of some substance above a specified baseline or reference plane. Since gases expand and fill whatever container they are in, level is a variable that is measured only for liquids and solids.

VOLUME is a measure of the amount of space occupied by a substance.

TEMPERATURE is a measure of how hot or how cold something is, as compared with the temperature of another body or substance. As we will see later, temperature is a measure of one form of thermal energy.

HEAT is the flow of thermal energy. The distinction between heat and temperature is discussed later in this chapter.

ELECTRIC MAGNETIC RADIATION VARIABLES include all radiations from the electromagnetic spectrum: electric waves, radio waves, infrared waves, visible light waves, ultraviolet light waves, X rays, and gamma rays. Some of these electromagnetic radiation variables are quite familiar; others are not. At this point it is only necessary to understand that all of these variables are closely related and that they all might be defined as kinds of energy that can be emitted, propagated, and absorbed in the form of waves. The reason why each type of electromagnetic radiation produces its own special effect (electricity, radiant heat, light, etc.) is that each type of electromagnetic radiation has its own wavelength and its own particular frequency.

ELECTRIC VARIABLES are those that have to do with various properties or values of electricity. Electrical variables include (but are not limited to) electromotive force, current, resistance, conductance, conductivity, inductance, and capacitance. These and other electrical variables are discussed in detail in Basic Electricity, NavPers 10086-A.

FUNDAMENTAL DIMENSIONS

Practically all units of measurement are derived from a few basic quantities or **FUNDAMENTAL DIMENSIONS**, as they are sometimes called. In all commonly used systems of measurement, **LENGTH** and **TIME** are taken as two of the fundamental dimensions. A third is **MASS** in some systems and **FORCE** (or **WEIGHT**) in others. In all systems, **TEMPERATURE** is the fourth fundamental dimension.

The first three fundamental dimensions—length, time, and either mass or force—are sometimes called **MECHANICAL** quantities or dimensions. All other important mechanical

quantities can be defined in terms of these three fundamentals. Temperature, the fourth fundamental dimension, is in a different category because it is not a mechanical quantity. By using the three mechanical fundamental quantities and the quantity of temperature, practically all quantities of any importance may be derived.

SYSTEMS AND UNITS OF MEASUREMENT

It is often said that there are two systems of measurement—a metric system and a British system. Actually, however, there are several metric systems and several British systems. A more meaningful classification of systems of measurement can be made by saying that some systems are gravitational and others are absolute. In GRAVITATIONAL systems, the units of force are defined in terms of the effects of the force of gravity upon a standard sample of matter at a specified location on the surface of the earth. In ABSOLUTE systems, the units of force are defined in terms that are completely independent of the effects of the force of gravity. Thus a metric system could be either gravitational or absolute, and a British system could be either gravitational or absolute, depending upon the terms in which force is defined in the particular system.

MASS AND WEIGHT

To understand what is meant by gravitational and absolute systems of measurement, it is necessary to have a clear understanding of the difference between mass and weight. MASS, a measure of the total quantity of matter in an object or body, is completely independent of the force of gravity, so the mass of any given object is always the same, no matter where it is located on the surface of the earth; indeed, the body would have the same mass even if it were located at the center of the earth, on the moon, in outer space, or anywhere else. WEIGHT, on the other hand, is a measure of the force of attraction between the mass of the earth and the mass of another body or object. Since the force of attraction between the earth and another body is not identical in all places, the weight of a body depends upon the location of the body with respect to the earth.

The relationship between mass and weight can be understood from the equation

$$w = mg$$

where

w = weight

m = mass

g = acceleration due to gravity

The value for acceleration due to gravity (normally represented by the letter g) is almost constant for bodies at or near the surface of the earth. This value is approximately 32 feet per second per second in British systems of measurement, 9.8 meters per second per second in one metric system, and 980 centimeters per second per second in another metric system. More precise values of g , including variations that occur with changes in latitude and changes in elevation, may be obtained from physics and engineering textbooks and handbooks.

BASIC MECHANICAL UNITS

Table 3-1 shows the basic mechanical quantities of length, mass or force, and time, together with a number of derived units, used in several systems of measurement. By examining some of the units, we may see how force is defined and thus see why each system is called "absolute" or "gravitational," as the case may be. (Note: However, as an IM3 or an IM2, you will be primarily concerned with the MKS metric absolute system and the British FPS gravitational system which are in columns 1 and 5 respectively.)

In the metric absolute meter-kilogram-second (MKS) system of measurement, the unit of mass is the kilogram, the unit of length is the meter, the unit of time is the second, and the unit of acceleration is meters per second per second. (This is sometimes written as m/sec^2 .) The unit of force is called a NEWTON. By definition, 1 newton is the force required to accelerate a mass of 1 kilogram at the rate of 1 meter per second per second. In other words, the unit of force is defined in such a way that UNIT force gives UNIT acceleration to UNIT mass.

The same thing holds true in the other metric absolute system shown in table 3-1. In the metric absolute centimeter-gram-second (CGS) system of measurement, the gram is the unit of mass, the centimeter is the unit of length, the second is the unit of time, and centimeters per second per second (cm/sec^2) is the unit of acceleration. In this system, the unit of force is called a DYNE. By definition, 1 dyne is the force required to accelerate a mass

Table 3-1.—Units of Measurement in Several Common Systems.

	MKS Metric Absolute System	CGS Metric Absolute System	British FPS Absolute System	British Engineer- ing Gravitational System	British FPS Gravitational System
Length	meter (m)	centimeter (cm)	foot (ft)	foot (ft)	foot (ft)
Area	square meter (m ²)	square centimeter (cm ²)	square foot (ft ²)	square foot (ft ²)	square foot (ft ²)
Volume	cubic meter (m ³) or liter (l)	cubic centimeter (cm ³ or cc) or milliliter (ml)	cubic foot (ft ³)	cubic foot (ft ³)	cubic foot (ft ³)
Mass	kilogram (kg)	gram (g)	pound (lb)	slug	pound (lb)
Force (Weight)	newton (n, new, or nt)	dyne	poundal (pdl)	pound (lb) or pound-force (lbf)	pound (lb) or pound-force (lbf)
Time	second (sec)	second (sec)	second (sec)	second (sec)	second (sec)
Velocity	m/sec	cm/sec	ft/sec	ft/sec	ft/sec
Acceleration	m/sec ²	cm/sec ²	ft/sec ²	ft/sec ²	ft/sec ²
Pressure	nt/m ²	dynes/cm ²	pdl/ft ²	lb/ft ² or lbf/ft ²	lb/ft ² or lbf/ft ²
Energy	joule	erg	foot-poundal (ft-pdl)	foot-pound (ft-lb) or foot-pound- force (ft-lbf)	foot-pound (ft-lb) or foot-pound-force (ft-lbf)
Power	watt	ergs per second (erg/sec)	ft-pdl/sec	ft-lb/sec or ft-lbf/sec	ft-lb/sec or ft-lbf/sec

of 1 gram at the rate of 1 centimeter per second per second. Again, force is defined in such a way that UNIT force gives UNIT acceleration to UNIT mass.

The same applies to the British absolute foot-pound-second (FPS) system of measurement, where the pound is the unit of mass, the foot is the unit of length, the second is the unit of time, and feet per second per second is the unit of acceleration. In this system, the unit of force is called a POUNDAL. By definition, 1 poundal is the amount of force required to give a mass of 1 pound an acceleration of 1 foot per second per second. Again, force is defined in such a way that UNIT force gives UNIT acceleration to Unit mass.

Now let's look at a British gravitational system—the foot-pound-second (FPS) gravitational system that we use in the United States for most everyday measurements. The foot is

the unit of length, the pound is the unit of mass, the second is the unit of time, and feet per second per second is the unit of acceleration. In this system, the unit of force is called the POUND. (Actually, it should be called the POUND-FORCE; but this usage is rarely followed.) In this system, a force of 1 pound acting upon a mass of 1 pound produces an acceleration of 32 feet per second per second. Note that unit force does NOT produce unit acceleration when acting on unit mass; rather, unit force produces unit acceleration when acting on unit WEIGHT. Since force is defined in gravitational terms, rather than in absolute terms, we say that this is a gravitational system of measurement.

The gravitational system that is usually called the BRITISH ENGINEERING SYSTEM also uses the pound (or, more precisely, the pound-force) as the unit of force. But this system has

its own unit of mass: the SLUG. By definition, 1 slug is the quantity of mass that is accelerated at the rate of 1 foot per second per second when acted on by a force of 1 pound. In other words, 1 slug equals 32 pounds, 2 slugs equals 64 pounds, and so forth. By using the slug as the unit of mass, the British engineering system sets up consistent units of measurement in which unit force acting upon unit mass produces unit acceleration. Note, however, that this is still a gravitational system rather than an absolute system.

By this time it should be obvious that the relationships expressed in one system of measurement do not necessarily hold when a different system is used. When using any particular system, it is essential to understand the precise meaning of all terms used in that system. This is not always a simple matter, since there are an enormous number of possible combinations of units and in many cases the same word is used to express quite different ideas. Another source of confusion is the way in which the various systems of measurement are used. In everyday life we use the British gravitational FPS system. In scientific work we use one of the metric systems. In engineering and other technical fields we use a British system or a metric system, depending upon the field involved. The only way to avoid total confusion in the use of measurement terms is to make sure that you understand the precise meaning of each term, as it relates to the particular system being used.

The units shown in table 3-1 are only a few of the units that may be derived in each system. For example, the unit of pressure shown for both of the British gravitational systems is pounds per square foot (lb/ft^2 , or psf). However, the unit pounds per square inch (lb/in^2 , or psi) is equally acceptable and is very commonly used. Similar conversions can be made for any of the other units, as long as the basic relationships of the system are accurately maintained.

Converting basic mechanical units from one system of measurement to another is a fairly simple matter if you know how to work with fractions and decimals. If you are not completely sure of your handling of fractions and decimals, review the appropriate material in Mathematics, Vol. 1, NavPers 10069-C.

When converting values from a metric system to a British system (or vice versa) it is necessary to understand the units used in each system. Most of us know quite a bit about the

units commonly used in British systems, but less about the units used in metric systems. So let's take a look at the basic structure of the metric systems.

All metric systems of measurement are DECIMAL systems—that is, the sizes of the units vary by multiples of 10. This makes computations very simple. Another handy thing about the metric systems is that the prefixes for the names of the units tell you the relative sizes of the units. Take the prefix kilo-, for example. Kilo- indicates 1000; so a kilogram is 1000 grams, a kilometer is 1000 meters, and so forth. Or take the prefix milli-, for another example. Milli- indicates a thousandth. So 1 millimeter is 1 thousandth of a meter, 1 milligram is 1 thousandth of a gram, and so forth. Perhaps the best way to become familiar with the units in the metric systems is to associate the more commonly used prefixes with the positive and negative powers of 10, as shown in table 3-2.

Table 3-2.—Metric System Prefixes and Corresponding Positive and Negative Powers of 10.

METRIC SYSTEM PREFIXES	POSITIVE AND NEGATIVE POWERS OF 10
DEKA- or DECA	$10^1 = 10$
HECTO-	$10^2 = 100$
KILO-	$10^3 = 1000$
MEGA-	$10^6 = 1,000,000$
DECI-	$10^{-1} = 0.1$ (or $1/10$)
CENTI-	$10^{-2} = 0.01$ (or $1/100$)
MILLI-	$10^{-3} = 0.001$ (or $1/1000$)
MICRO-	$10^{-6} = 0.000001$ (or $1/1,000,000$)

Table 3-3 gives some selected values for mechanical units in British systems of measurement. Table 3-4 gives some selected values for mechanical units in metric systems of measurement. Table 3-5 gives some British-metric and metric-British equivalents. The examples given in these tables are chosen primarily to help you develop an understanding of the relative sizes of the mechanical units. More complete tables are available in many physics and engineering textbooks and handbooks.

Table 3-3.—Selected Values of Mechanical Units in British Systems of Measurement.

TYPE OF MECHANICAL UNIT	SELECTED VALUES
LENGTH	12 inches (in.) = 1 foot (ft) 3 ft = 1 yard (yd) 5280 ft = 1 mile (mi) 1760 yd = 1 mi
AREA	144 square inches = 1 square foot (sq in. or in. ²) (sq ft or ft ²) 9 ft ² = 1 yd ²
VOLUME	1728 cubic inches = 1 cubic foot (cu in. or in. ³) (sq ft or ft ³) 27 ft ³ = 1 yd ³
FORCE (WEIGHT)	16 ounces (oz) = 1 pound (lb) 2000 lb = 1 ton
VELOCITY	60 miles per hour = 88 feet per (mi/hr or mph) second (ft/sec)

Table 3-4.—Selected Values of Mechanical Units in Metric Systems of Measurement

TYPE OF MECHANICAL UNIT	SELECTED VALUES
LENGTH	10 milli-meters (mm) = 1 centimeter (cm) 10 cm = 1 decimeter (dm) 10 dm = 1 meter (m) 100 cm = 1 meter 1000 mm = 1 meter 10 m = 1 dekameter (dkm) 100 m = 1 hectometer (hm) 1000 m = 1 kilometer (km)
AREA	100 square milli-meters (mm ²) = 1 cm ² 100 cm ² = 1 dm ² 100 dm ² = 1 m ²
VOLUME	1000 cubic milli-meters (mm ³) = 1 cm ³ 1000 cm ³ = 1 dm ³ 1000 dm ³ = 1 m ³

Table 3-4.—Selected Values of Mechanical Units in Metric Systems of Measurement (Continued)

VOLUME (Contd)	1 milliliter (ml) = 1 cm ³ 1000 ml = 1 liter (l) 100 centiliters (cl) = 1 liter 10 deciliters (dl) = 1 liter
MASS	1000 milli-grams (mg) = 1 gram (g) 100 centi-grams (cg) = 1 gram 1000 grams = 1 kilogram (kg)

Table 3-5.—Selected British-Metric and Metric-British Conversions

TYPE OF MECHANICAL UNIT	BRITISH-METRIC CONVERSIONS
LENGTH	1 inch = 2.540 centimeters 1 foot = 0.3048 meter 1 yard = 0.9144 meter 1 mile = 1.6093 kilometers 1 mile = 1609.3 meters
AREA	1 in. ² = 6.452 cm ² 1 ft ² = 929 cm ² 1 yd ² = 0.8361 m ² 1 mi ² = 2.59 km ²
VOLUME	1 in. ³ = 16.387 cm ³ 1 ft ³ = 0.0283 m ³ 1 yd ³ = 0.7646 m ³ 231 in. ³ = 3.7853 liters
WEIGHT	1 grain = 0.0648 gram 1 ounce = 23.3495 grams 1 pound = 453.592 grams 1 pound = 0.4536 kilograms
METRIC-BRITISH CONVERSIONS	
LENGTH	1 centimeter = 0.3937 inch 1 meter = 39.37 inches 1 kilometer = 0.62137 mile
AREA	100 mm ² = 0.15499 in. ² 100 cm ² = 15.499 in. ² 100 m ² = 119.6 yd ² 1 km ² = 0.386 mi ²

Table 3-5.—Selected British-Metric and Metric-British Conversions (Contd)

METRIC-BRITISH CONVERSIONS	
VOLUME	$1000 \text{ mm}^3 = 0.06102 \text{ in.}^3$
	$1000 \text{ cm}^3 = 61.02 \text{ in.}^3$
	$1 \text{ m}^3 = 35.314 \text{ ft}^3$
	1 liter = 1.0567 liquid quarts
WEIGHT	1 gram = 15.4324 grains
	1 gram = 0.03527 ounce
	1 gram = 0.002205 pound
	1 kilogram = 2.2046 pounds

TEMPERATURE UNITS

Temperature is measured by bringing a measuring system (such as a thermometer) into contact with the system in which we need to measure the temperature. We then measure some property of the measuring system—the expansion of a liquid, the pressure of a gas, electromotive force, electrical resistance, or some other mechanical, electrical, or optical property that has a definite and known relationship with temperature. Thus we infer the temperature of the measured system by the measurement of some property of the measuring system.

But the measurement of a property other than temperature will take us only so far in utilizing the measurement of temperature. For convenience in comparing temperatures and in noting changes in temperature, we must be able to assign a numerical value to any given temperature. For this we need temperature scales.

Until 1954, temperature scales were constructed around the boiling point and the freezing point of pure water at atmospheric pressure. These two fixed and reproducible points were used to define a fairly large temperature interval which was then subdivided into the uniform smaller intervals called DEGREES. The two most familiar temperature scales constructed in this manner are the Celsius scale and the Fahrenheit scale.

The Celsius scale is often called the centigrade scale in the United States and Great Britain. By international agreement, however, the name was changed from centigrade to Celsius in honor of the eighteenth-century Swedish

astronomer, Anders Celsius. The symbol for a degree on this scale (no matter whether it is called Celsius or centigrade) is °C. The Celsius scale takes 0° C as the freezing point and 100° C as the boiling point of pure water at atmospheric pressure. The Fahrenheit scale takes 32° F as the freezing point and 212° F as the boiling point of pure water at atmospheric pressure. The interval between freezing point and boiling point is divided into 100 degrees on the Celsius scale and divided into 180 degrees on the Fahrenheit scale.

Since the actual value of the interval between freezing point and boiling point is identical, it is apparent that numerical readings on Celsius and Fahrenheit thermometers have no absolute significance and that the size of the degree is arbitrarily chosen for each scale. The relationship between degrees Celsius and degrees Fahrenheit is given by the formulas

$$^{\circ}\text{F} = \frac{9}{5} ^{\circ}\text{C} + 32$$

$$\text{C} - ^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$$

Many people have trouble remembering these formulas, with the result that they either get them mixed up or have to look them up in a book every time a conversion is necessary. If you concentrate on trying to remember the basic relationships given by these formulas, you may find it easier to make conversions. The essential points to remember are these:

1. Celsius degrees are larger than Fahrenheit degrees. One Celsius degree is equal to 1.8 Fahrenheit degrees, and each Fahrenheit degree is only 5/9 of a Celsius degree.

2. The zero point on the Celsius scale represents exactly the same temperature as the 32-degree point on the Fahrenheit scale.

3. The temperatures 100°C and 212°F are identical.

In some scientific and engineering work, particularly where heat calculations are involved, an absolute temperature scale is used. The zero point on an absolute temperature scale is the point called ABSOLUTE ZERO. Absolute zero is determined theoretically, rather than by actual measurement. Since the pressure of a gas at constant volume is directly proportional to the temperature, it is logical to assume that the pressure of a gas is a valid measure of its temperature. On this assumption, the lowest possible temperature (absolute zero) is defined as

the temperature at which the pressure of a gas would be zero.

Two absolute temperature scales have been in use for many years. The RANKINE absolute scale is an extension of the Fahrenheit scale; it is sometimes called the Fahrenheit absolute scale. Degrees on the Rankine scale are the same size as degrees on the Fahrenheit scale, but the zero point on the Rankine scale is at -459.67° Fahrenheit. In other words, absolute zero is zero on the Rankine scale and -459.67 degrees on the Fahrenheit scale.

A second absolute scale, the KELVIN, is more widely used than the Rankine. The Kelvin scale was originally conceived as an extension of the Celsius scale, with degrees on the same size but with the zero point shifted to absolute zero. Absolute zero on the Celsius scale is -273.15° C.

In 1954, a new international absolute scale was developed. The new scale was based upon one fixed point, rather than two. The one fixed point was the triple point of water—that is, the point at which all three phases of water (solid, liquid, and vapor) can exist together in equilibrium. The triple point of water, which is 0.01° C above the freezing point of water, was chosen because it can be reproduced with much greater accuracy than either the freezing point or the boiling point. On this new scale, the triple point was given the value 273.17 K. Note that neither the word “degrees” nor the symbol $^{\circ}$ is used; instead, the unit is called a “kelvin” and the symbol is K rather than $^{\circ}$ K.

In 1960, when the triple point of water was finally adopted as the fundamental reference for this temperature scale, the scale was given the name of INTERNATIONAL PRACTICAL TEMPERATURE SCALE. However, you will often see this scale referred to as the Kelvin scale.

Although the triple point of water is considered the basic or fundamental reference for the International Practical Temperature Scale, five other fixed points are used to help define the scale. These are the freezing point of gold, the freezing point of silver, the boiling point of sulfur, the boiling point of water, and the boiling point of oxygen.

Figure 3-1 is a comparison of the Fahrenheit, Rankine (or Fahrenheit absolute), Celsius, and International Practical (or Kelvin) temperature scales. All of the temperature points listed above absolute zero are considered as fixed points on the Kelvin scale EXCEPT for the freezing point of water. The other scales, as

previously mentioned, are based on the freezing and boiling points of water.

PRESSURE UNITS

Pressure is defined as FORCE PER UNIT AREA.

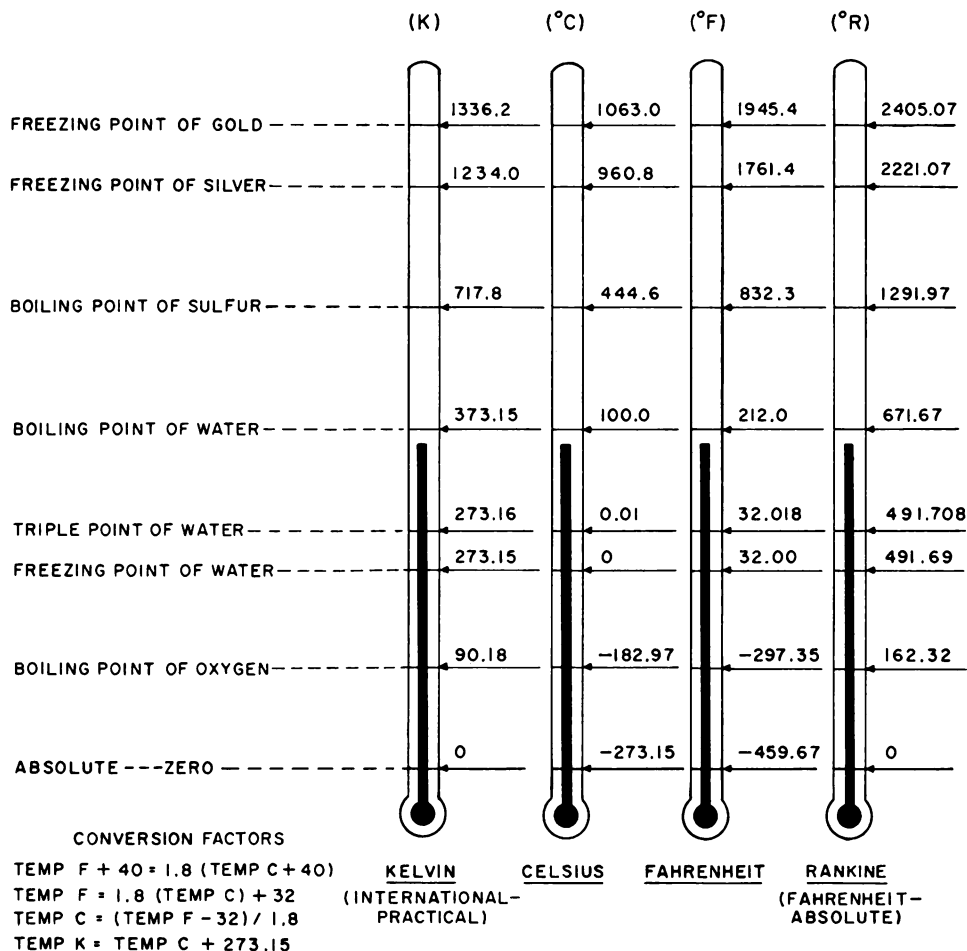
The simplest pressure units are ones that indicate how much force is applied to an area of a certain size. These units include pounds per square inch, pounds per square feet, ounces per square inch, newtons per square millimeter, and dynes per square centimeter, depending upon the system being used.

You will also find another kind of pressure unit, and this type appears to involve length. These units include inches of water, inches of mercury (Hg), and inches of some other liquid of known density. Actually, these units do not involve length as a fundamental dimension. Rather, length is taken as a measure of force or weight. For example, a reading of 1 inch of water (1 in. H₂O) means that the exerted pressure is able to support a column of water 1 inch high, or that a column of water in a U-tube would be displaced 1 inch by the pressure being measured. Similarly, a reading of 12 inches of mercury (12 in. Hg) means that the measured pressure is sufficient to support a column of mercury 12 inches high. What is really being expressed (even though it is not mentioned in the pressure unit) is the fact that a certain quantity of material (water, mercury, etc.) of known density will exert a certain definite force upon a specified area. Pressure is still FORCE PER UNIT AREA, even if the pressure unit refers to inches of some liquid.

It is often necessary to convert from one type of pressure unit to another. Complete conversion tables may be found in many texts and handbooks. Conversion factors for pounds per square inch, inches of mercury, and inches of water are:

1 in. Hg	- 0.49 psi
1 psi	- 2.036 in. Hg
1 in. H ₂ O	- 0.036 psi
1 psi	- 27.68 in. H ₂ O
1 in. H ₂ O	- 0.074 in. Hg
1 in. Hg	- 13.6 in. H ₂ O

In interpreting pressure measurements, a great deal of confusion arises because the zero point on must pressure gages represents atmospheric pressure rather than zero absolute



33.11(147B)

Figure 3-1.—Comparison of temperature scales.

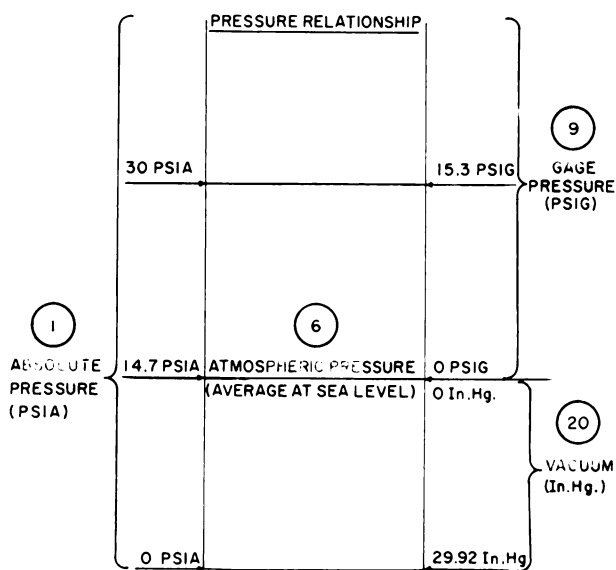
pressure. Thus it is often necessary to specify the kind of pressure being measured under any given conditions. To clarify the numerous meanings of the word pressure, let's take a look at the relationships among gage pressure, atmospheric pressure, vacuum, and absolute pressure, as illustrated in figure 3-2.

GAGE PRESSURE is the pressure actually shown on the dial of a gage that registers pressure at or above atmospheric pressure. An ordinary pressure gage reading of zero does NOT mean that there is no pressure in the absolute sense; rather, it means that there is no pressure in excess of atmospheric pressure.

Gage pressure should be expressed as pounds per square inch gage (psig). By common convention, however, gage pressure is assumed

when pressure is given in psi, and psig is used chiefly when some possibility of confusion exists. Absolute pressure, on the other hand, is always expressed as pounds per square inch absolute (psia) and pounds per square foot absolute (psfa).

ATMOSPHERIC PRESSURE is the pressure exerted by the weight of the atmosphere. At sea level, the **AVERAGE** pressure of the atmosphere is sufficient to hold a column of mercury at a height of 76.0 millimeters or 29.92 inches of mercury. Since a column of mercury 1 inch high exerts a pressure of 0.49 pound per square inch, a column of mercury 29.92 inches high exerts a pressure that is equal to 29.92×0.49 , or approximately 14.7 psi. Since we are dealing now in absolute pressure, we say that the average atmospheric pressure at sea level is 14.7 pounds



147.181

Figure 3-2.—Relationships of gage pressure, atmospheric pressure, vacuum, and absolute pressure.

per square inch ABSOLUTE. It is zero on the ordinary pressure gage.

Notice, however, that the figure of 14.7 pounds per square inch absolute (psia) represents the AVERAGE atmospheric pressure at sea level, and does not always represent the ACTUAL pressure being exerted by the atmosphere at the moment that a gage is being read.

BAROMETRIC PRESSURE is the term used to describe the actual atmospheric pressure that exists at any given moment. Barometric pressure may be measured by a simple mercury column or by a specially designed instrument called an aneroid barometer.

A space in which the pressure is less than atmospheric pressure is said to be under VACUUM. The amount of vacuum is expressed in terms of the difference between the absolute pressure in the space and the pressure of the atmosphere. Most commonly, vacuum is expressed in inches of mercury, with the vacuum gage scale marked from 0 to 30 inches of mercury. When a vacuum gage reads zero, the pressure in the space is the same as atmospheric pressure—or, in other words, there is no vacuum. A vacuum gage reading of 29.92 inches of mercury would indicate a perfect (or nearly perfect) vacuum. In actual practice, it is

impossible to obtain a perfect vacuum even under laboratory conditions.

ABSOLUTE PRESSURE is atmospheric pressure PLUS gage pressure of MINUS vacuum. For example, a gage pressure of 300 psig equals an absolute pressure of 314.7 psia ($300 + 14.7$). Or, for another example, consider a space in which the measured vacuum is 10 inches of mercury vacuum; the absolute pressure in this space must then be 19.92 or approximately 20 inches of mercury absolute. It is important to note that the amount of pressure in a space under vacuum can ONLY be expressed in terms of absolute pressure.

You may have noticed that sometimes we say psig to indicate gage pressure and other times we merely say psi. By common convention, gage pressure is always assumed when pressure is given in pounds per square inch, pounds per square foot, or similar units. The "g" (for gage) is added only when there is some possibility of confusion. Absolute pressure, on the other hand, is ALWAYS expressed as pounds per square inch absolute (psia), pounds per square foot absolute (psfa), and so forth. It is always necessary to establish clearly just what kind of pressure we are talking about, unless this is very clear from the nature of the discussion.

OTHER UNITS

To this point, we have considered only the most basic and most common units of measurement. It is important to remember that hundreds of other units can be derived from these units, and that specialized fields require specialized units of measurement. Additional units of measurement are introduced in appropriate places throughout the remainder of this training manual. When you encounter more complicated units of measurement, you may find it helpful to review the basic information given here previously.

STANDARDS OF MEASUREMENT

The importance of having precise and uniform standards of measurement is recognized by all the major countries of the world, and international conferences on weights and measures are held from time to time. The International Bureau of Weights and Measures is in France. Each major country has its own bureau or office charged with the responsibility of maintaining the required measurement standards, including

the basic standards of length, mass, and time. In the United States, the National Bureau of Standards (NBS) is responsible for maintaining basic standards and for prescribing precise measuring techniques.

LENGTH

Until quite recently, the international standard of length was a platinum-iridium alloy bar kept at the International Bureau of Weights and Measures in France. By definition, the standard meter was the distance between two parallel lines marked on this bar, measured at 0° C. Copies of this international standard were maintained by other countries; the United States standard meter bar was maintained at the National Bureau of Standards in Washington, D.C.

Note that the standard of length was the meter even for countries that were not on the metric system. The yard was defined in terms of the meter, 1 yard being equal to 0.9144 meter.

In 1960, the standard of length was changed by international agreement to an atomic constant: the wavelength of the orange-red light emitted by individual atoms of krypton-86 in a tube filled with krypton gas in which an electrical discharge is maintained. By definition, 1 meter is equal to 1,650,763.73 wavelengths of the orange-red light of krypton-86, and 1 inch is equal to 41,929,399 wavelengths. A device called an OPTICAL INTERFEROMETER is used to determine the number of wavelengths of the orange-red light of krypton-86 in an unknown length.

MASS

The standard of mass is the mass of a cylinder of platinum-iridium alloy defined as having a mass of 1 kilogram. The international standard kilogram mass is kept at the International Bureau of Weights and Measures in France. The United States standard kilogram mass is kept at the National Bureau of Standards.

The standard of mass is kept in a vault. Not more than once a year, the standard is removed from the vault and used for checking the values of smaller standards. The United States standard kilogram mass has been taken to France twice in the last seven years for comparison with the international standard. Every precaution is taken to keep the kilogram standard mass in perfect condition, free of nicks, scratches, and corrosion. The standard is always handled with forceps; it is never touched by human hands.

When the national standard is compared on a precision balance with high precision copies, the copies are found to be accurate to within one part in 100 million.

TIME

Before 1960, the standard of time was the MEAN SOLAR SECOND—that is, $1/86,400$ of a mean solar day, as determined by successive appearances of the sun overhead, averaged over a year. In 1960, the standard of time was changed to the TROPICAL YEAR 1900, which is the time it took the sun to move from a designated point back to the same point in the year 1900. By definition, 1 second was equal to $1/31,556,925.9747$ of the tropical year 1900. The subdivision of the tropical year 1900 into smaller time intervals was accomplished by means of laboratory-type pendulum clocks, together with observation of natural phenomena such as the nightly movement of the stars and the moon.

Although the standard of time was changed to the tropical year 1900 in 1960, the same General Conference of Weights and Measures that approved this change also urged that work go forward on the development of an atomic clock. In 1967, the General Conference of Weights and Measures adopted as the basic standard of time the time required for the transition between two energy states of the cesium-133 atom. In accordance with this standard, 1 second is defined as 9,192,631,770 cycles of this particular transition in the cesium-133 atom.

The United States standard of time is maintained by a cesium clock which is kept at the National Bureau of Standards laboratories in Boulder, Colorado. The time signals that are broadcast by four radio stations operated by the National Bureau of Standards are based on this cesium clock.

NAVY CALIBRATION PROGRAM

The calibration of all measuring devices begins with and is dependent upon the basic international and national standards of measurement just discussed. Obviously, however, we can't rush off to the National Bureau of Standards every time we need to measure a length, a mass, a weight, or an interval of time. Therefore, the National Bureau of Standards prepares and calibrates a great many practical standards that can be used by government and industry. Government and industry, in turn, prepare and calibrate their

own practical standards. Thus there is a continuous linkage of measurement standards that begins with the international standards, comes down through the national standards, and works all the way on down to the rulers, weights, clocks, gages, and other devices that we use for everyday measurement.

As a Navy Instrumentman, you are very much a part of this continuous chain of measurement standards. To understand just how you fit in, you must know something about the Navy Calibration Program. The basic structure of this program is shown in figure 3-3.

We have already seen that the National Bureau of Standards is the highest level standards agency in the United States and that it has custody of this Nation's basic physical standards. The National Bureau of Standards provides the common reference for all measurements and certifies the Navy Standards that are maintained by the Navy Type I Standards Laboratories.

The Navy Type I Standards Laboratories maintain the highest standards within the Navy Calibration Program. The Type I Standards Laboratories obtain calibration services from the National Bureau of Standards and provide

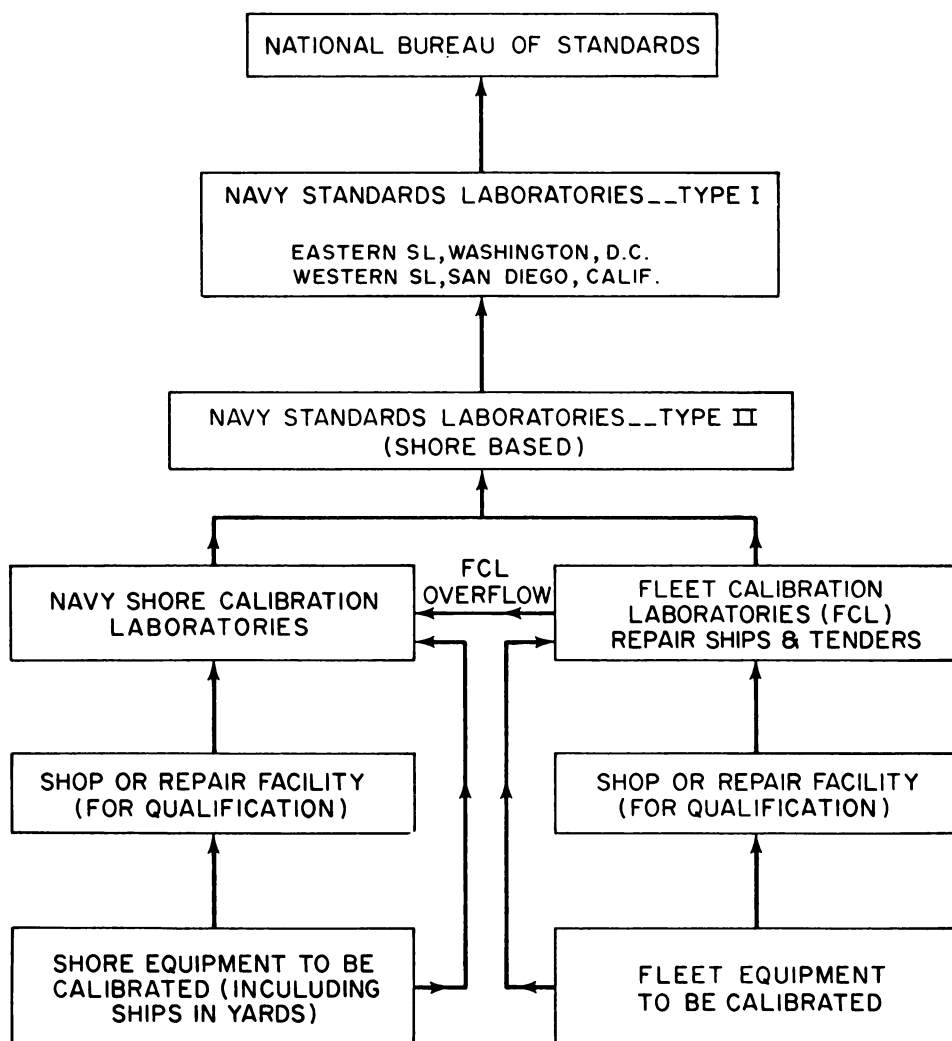


Figure 3-3.—Navy Calibration Program.

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calibration of standards and associated measuring equipment received from Type II Standards Laboratories. There are only two Type I Standards Laboratories: the Eastern SL, in Washington, D. C., and the Western SL, in San Diego, California.

Navy Standards Laboratories designated as Type II furnish the second highest level of calibration services to assigned geographical areas within the Naval Establishment. The Type II Standards Laboratories obtain standards calibration services from the cognizant Type I Standards Laboratory and calibrate standards and associated measuring equipment received from lower level laboratories. There are half a dozen Type II Navy Standards Laboratories, located in various shore activities throughout the United States.

Navy Calibration Laboratories furnish the third highest level of calibration services in the Navy Calibration Program. The Navy Calibration Laboratories obtain calibration services from the Type II Standards Laboratories and they calibrate test equipment received from ships and from shore activities. There are two basic types of Navy Calibration Laboratories. FLEET Calibration Laboratories, which are located on repair ships and tenders (MIRCS) receive and calibrate fleet equipment only. SHORE Calibration Laboratories, which are located in various shore activities of the Navy, receive and calibrate shore equipment and also handle the overflow from Fleet Calibration Laboratories.

As indicated in figure 3-3, equipment to be calibrated may go directly to a Navy Calibration Laboratory or it may go to a shop or repair facility for "qualification." Qualification is not the same as calibration, and the two terms should be clearly distinguished.

CALIBRATION is the process by which Calibration Laboratories and Standards Laboratories compare a standard or a measuring instrument with a standard of higher accuracy in order to ensure that the item being compared is accurate within specified limits throughout its entire range. The calibration process involves the use of approved instrument calibration procedures; it may also include any adjustments or incidental repairs necessary to bring the standard or instrument being calibrated within specified limits. Calibration of standards is considered mandatory.

QUALIFICATION is the process by which an activity other than officially designated Standards

Laboratories or Calibration Laboratories compares a test or measuring instrument with one of higher accuracy in order to determine the need for calibration. Qualification may be performed by ships or stations that have been furnished with approved measurement standards and procedures. However, the instrument used to qualify the test or measuring equipment should be calibrated periodically by a Navy Standards Laboratory or a Navy Calibration Laboratory in order for the qualification to be valid.

Several additional terms used in connection with the Navy Calibration Program are defined in the following paragraphs. It is important to understand the precise meaning of these terms and to use them correctly.

CALIBRATION PROCEDURE is the term used for a document that outlines the steps and operations to be followed by standards and calibration laboratory personnel in the performance of instrument calibration.

CALIBRATION CYCLE is the length of time between calibration services during which each test equipment is expected to maintain reliable measurement capability. The Metrology Requirements List (NAVAIR 17-35MTL-1 NAV-SHIPS) is available and used to find the following information relating to a particular instrument:

- (1) Instrument Calibration Recall Intervals
- (2) Applicable Procedure Numbers
- (3) Related Technical Numbers

(Note: The Metrology Requirements List is where you can find calibration cycles.)

CROSS-CHECKS involve the comparison of two or more instruments of equal or near equal accuracy for the sole purpose of determining if the values of any of the instruments have shifted significantly. The cross-check is used as an interim measure until a standard or instrument of sufficiently high accuracy can be used to calibrate or qualify an instrument.

INCIDENTAL REPAIR is the term used to describe those repairs found necessary during the calibration of an operable equipment to bring it within its specified tolerances. Incidental repair includes the replacement of parts which have changed value sufficiently to prevent calibration but not enough to render the equipment inoperative. Incidental repair is normally performed in the laboratories in conjunction with the calibration of test equipment or standards.

LABORATORY STANDARD is the term used to identify a laboratory-type device that is used

to maintain the continuity of values in units of measurement by periodic comparison with standards of Navy laboratories or with standards maintained by the National Bureau of Standards. A laboratory standard is used to calibrate a standard of lesser accuracy.

An acceptance for LIMITED USE indicates that an instrument which has failed certain tests or which has not been tested against all acceptance criteria is nevertheless suitable for certain specific (limited) usage. In such a situation, a LIMITED USE label (rather than a CALIBRATED or QUALIFIED label) is placed on the instrument to draw attention to the conditional acceptance. In addition to the label, a LIMITED USE tag is attached to the instrument. This tag is filled in by the servicing activity; it includes a full description of the reservations or precautions which should be observed in using the instrument. The label and the tag indicating that the instrument is suitable only for limited use must remain on the instrument until the next calibration or qualification.

The term REJECTED is used when an instrument fails to meet the acceptance criteria during calibration or qualification and when it cannot be made to meet these criteria by incidental repair. Under these conditions, a REJECTED label is placed on the instrument and all other servicing labels are removed. In addition to the label, a REJECTED tag is attached to the instrument. The tag, which is filled in by the servicing activity, gives the reason for rejection and such other information as may be required.

REPAIR is defined as the repair and/or replacement of malfunctioning parts of a measuring instrument or standard to the degree required to restore the instrument or standard to an operating condition.

TRACEABILITY is when the accuracy of a measurement made by the fleet can be directly traceable through the echelons of calibration to Reference Standards maintained by the National Bureau of Standards (unbroken chain of properly conducted calibrations).

INSTRUMENT ACCURACY

As we have seen, all measurement is subject to a certain amount of error. The international and national standards have some error, even though it is almost unbelievably small. The error in secondary standards, while still extremely small, is somewhat greater than the error in the primary standards. When we get down to the

actual measuring devices used even for precision measurement, the error is larger still.

Although it may sound backwards, the ACCURACY of an instrument is expressed by giving the amount of ERROR of the instrument. For example, an instrument with an accuracy of 1 percent is said to have an error of ± 1 percent.

The error of an instrument is the difference between the reading shown on the instrument and the true value of the variable being measured. Error may be expressed in scale units, in percent of scale span, in percent of range, or in percent of indicated value (iv). By agreement among instrument manufacturers, error in instruments with uniform scales is most commonly expressed as a percentage of the full scale length, regardless of where the measurement is made on the scale. The exception to this general rule is that the measurement is not made at the extreme top or the extreme bottom of the scale, since an instrument is almost sure to be less accurate in these areas than in the working range of the scale.

Using the full scale length as the basis for determining instrument error can lead to some confusion. For example, consider several pressure gages, each one of which has a guaranteed accuracy of 1 percent. If the scale reads 0 to 30 psi, the allowable error is ± 0.3 psi. If the scale reads 0 to 100 psi, the allowable error is ± 1 psi. If the scale reads 0 to 500 psi, the allowable error is ± 5 psi. If the scale reads 0 to 1000, the allowable error is ± 10 psi.

As far as ACCURACY RATIOS are concerned, there are recommended low and high accuracy ratios that should exist between the test and measuring equipment, and the measuring system or Standard, also between echelons of Standards.

The lower limit ratio should be at least 4 to 1; a ratio below this limit is impracticable for technical reasons. The upper limit ratio should not be more than 10 to 1; if the ratio is higher, equipment costs will become excessive.

Calibration error is taken care of by LINEARITY and RANGE ERRORS. Linearity error is when the lowest and the highest indications are correct, and there is an error in between these indications. Range error occurs when the lowest indication is on and the highest indication is off, above or below the true value.

If an instrument does not give the same reading when it comes from the top of the scale down to the point of measurement as it does when it goes from the bottom of the scale up to the point

of measurement, the error is called **HYSTERESIS**. Hysteresis occurs from a variety of factors that cause loss of energy within the instrument; it might occur because of friction or binding of parts, fatigue of a spring, excessive play in gears, or other mechanical difficulties.

Because there will always be some error of measurement, and because the error may actually be considerably greater than that indicated by the percentage of guaranteed accuracy, the calibration of any measuring device requires the highest possible precision. Error is bound to occur; but it is up to the Instrumentman to make sure that the error is not increased by incorrect or inaccurate calibration procedures.

INSTRUMENT SENSITIVITY

Instrument sensitivity is sometimes confused with instrument accuracy. This is a big mistake.

The sensitivity of an instrument refers to the ability of the instrument to respond to changes in the value of the measured variable. If an instrument can respond to very small changes in the measured variable, it is a very sensitive instrument; if larger changes in the measured variable are required to produce effective motion of the measuring element, the instrument is less sensitive.

Sensitivity is quite directly related to friction within an instrument. An instrument that has relatively small energy losses because of friction will, all other things being equal, be more sensitive than an instrument with relatively large friction losses.

CHAPTER 4

BASIC PRINCIPLES OF INSTRUMENT DESIGN

In the previous chapter dealing with principles of measurement, we were concerned (directly or indirectly) with a number of basic principles and concepts in the field of physics. Now, in this chapter, we will take up certain additional principles of physics that have an important bearing upon design of instruments. We are primarily concerned here with broad, general principles that apply to more than one kind of measuring device; principles that apply only to specific types of equipment are, as a rule, covered in the chapters of this training manual that deal with such specific equipment.

KINDS OF ENERGY

Can you define energy? Although almost everybody has a general idea of what the word means, a good definition is hard to find. Most commonly, perhaps, energy is defined as "the capacity for doing work." This is not a very complete definition. Energy can produce other effects that could not possibly be considered "work." For example, heat can flow from one object to another without doing any work; yet heat is a form of energy and the process of heat transfer is a process that produces an effect.

A better definition of energy, therefore, states that "energy is the capacity for producing an effect." This is the definition that is followed in this training course.

Energy exists in many forms. For convenience, we usually classify energy according to the size and nature of the bodies or particles with which the energy is associated. Thus we say that **MECHANICAL ENERGY** is the energy associated with large bodies or objects—usually, things that are big enough to see. **THERMAL ENERGY** is the energy associated with molecules. **CHEMICAL ENERGY** is energy that arises from the forces that bind the atoms together in a molecule. (Chemical energy is demonstrated

whenever combustion or any other chemical reaction takes place.) Energy from the **ELECTROMAGNETIC SPECTRUM** (electricity, radiant heat, light, etc.) is energy that is associated with particles that are even smaller than atoms.

Each of these types of energy (mechanical, thermal, chemical, etc.) must also be classified as being either (1) stored energy, or (2) energy in transition.

STORED ENERGY can be thought of as energy that is actually "contained in" or "stored in" a substance or a system. There are two kinds of stored energy: (1) potential energy, and (2) kinetic energy. When energy is stored in a substance or system because of the relative **POSITIONS** of two or more objects or particles, we call it potential energy. When energy is stored in a substance or system because of the relative **VELOCITIES** of two or more objects or particles, we call it kinetic energy.

ENERGY IN TRANSITION is energy that is in the process of being transferred from one object or system to another. The two kinds of energy in transition that we will be most concerned with are **WORK**, which is mechanical energy in transition, and **HEAT**, which is thermal energy in transition.

MECHANICAL ENERGY

Mechanical energy, as we have seen, is the energy associated with relatively large objects or bodies. The two stored forms of mechanical energy are mechanical potential energy and mechanical kinetic energy; mechanical energy in transition is called work.

Stored Mechanical Energy

Mechanical **POTENTIAL** energy exists because of the relative positions of two or more objects. For example, a rock resting on the edge

of a cliff in such a position that it will fall freely if pushed has mechanical potential energy. Water at the top of a dam has mechanical potential energy. A sled being held at the top of an icy hill has mechanical potential energy.

Mechanical KINETIC energy exists because of the relative velocities of two or more objects. If you push that rock, open the gate of the dam, or let go of the sled, something will move. The rock will fall, the water will flow, the sled will slide down the hill. In each case the mechanical potential energy will be changed to mechanical kinetic energy.

Notice that mechanical potential energy and mechanical kinetic energy are both STORED forms of energy. It is easy to see why we regard mechanical potential energy as stored, but it is not so easy to see why mechanical kinetic energy is stored. Part of the trouble occurs because mechanical kinetic energy is often referred to as "the energy of motion." Kinetic energy is energy OF motion, but it is not energy IN motion or in transition from one object or system to another.

Mechanical potential energy is measured in foot-pounds. Consider, for example, the rock at the top of the cliff. If the rock weighs 5 pounds and if the distance from the rock to the earth at the base of the cliff is 100-feet, 500 foot-pounds of potential energy exist because of the relative positions of the rock and the earth. Another way of expressing this idea is by the formula

$$PE = w \times d$$

where

PE = potential energy (in foot-pounds)
w = total weight of the object (in pounds)
d = distance between the earth and the object (in feet)

Mechanical kinetic energy is also measured in foot-pounds. The formula for calculating mechanical kinetic energy is

$$KE = \frac{wv^2}{2g}$$

where

KE = kinetic energy
w = weight of the object (in pounds)
v = velocity of the object (in feet per second)
g = acceleration due to gravity (32 feet per second per second)

Mechanical potential energy and mechanical kinetic energy can be converted from one form to another, in either direction. If you push that 5-pound rock over the edge of the 100-foot cliff, it begins to fall; and as it falls it loses potential energy and gains kinetic energy. At any given moment, the TOTAL AMOUNT of stored mechanical energy is the same—that is, 500 foot-pounds. But the proportions of potential energy and kinetic energy are constantly changing as the rock is falling. At the very beginning of the fall, all the mechanical energy is stored as mechanical potential energy; at the end of the fall, all the stored mechanical energy is mechanical kinetic energy.

A pendulum provides another example of conversion between mechanical potential energy and mechanical kinetic energy. At its uppermost position, the pendulum has only potential energy. As it begins to move downward, it loses potential energy and gains kinetic energy. At the bottom point, the potential energy is zero and the kinetic energy is at the maximum value. As the pendulum moves upward on the other side, kinetic energy is converted into potential energy—that is, kinetic energy decreases and potential energy increases.

Mechanical Energy in Transition

Mechanical energy in transition is called work. When an object is moved through a distance against a resisting force, we say that work has been done. The formula for calculating work is

$$Wk = f \times d$$

where

Wk = work (in foot-pounds)
f = force (in pounds)
d = distance (in feet)

As may be seen, you need to know how much force is exerted and the distance through which the force acts in order to know how much work is done. The unit of force used here is the pound. When work is done against gravity, the force required to move an object is equal to the weight of the object, since weight is a measure of the gravitational attraction between the earth and some other body or object. When work is being done against gravity, then, force and weight are identical. If you move that 5-pound rock from

the base of the 100-foot cliff to the top of the cliff, you will accomplish 500 foot-pounds of work.

Work is also done against forces other than the force of gravity. When you push an object across the deck, you are doing work against friction. The amount of work done in this case is still calculated by the formula $W_k = f \times d$. The force is still measured in pounds, but in this case the force is not simply the weight of the object; instead, it is the amount of force required to overcome friction and slide the object over the surface of the deck.

It is important to note that no work is done unless something is displaced from its previous position. If you lift a 5-pound weight from the floor to a table that is 3 feet high, you have done 15 foot-pounds of work. But if you just stand and hold the 5-pound weight, you are not performing work in the technical sense of the term. Even though you may feel as though you are working, all you are doing is exerting force in order to support the weight against the action of the force of gravity. The forces are balanced; there is no motion or displacement of the weight, so no work is done.

If the force and the displacement are neither acting in the same direction nor acting in total opposition, work is done only by that component of the force which is acting in the direction of the displacement of the body. A man pushing a lawnmower, for example, is exerting some force that acts in the direction in which the lawnmower is moving; but he is also exerting some force that acts downward, at right angles to the direction of displacement. In this case, only the forward component of the exerted force results in work—that is, only the forward component of the force results in forward movement of the lawnmower.

Work is energy in transition because it occurs only temporarily, between other forms of energy. Work must always begin and end as stored energy.

Units of Mechanical Energy

Mechanical potential energy, mechanical kinetic energy, and work are all measured in the same unit. Up to this point, we have considered this unit to be the foot-pound: 1 foot-pound of work is done when a force of 1 pound acts through a distance of 1 foot, and 1 foot-pound of mechanical potential energy or mechanical

kinetic energy is the amount of energy required to accomplish 1 foot-pound of work.

The foot-pound unit is commonly used in British systems of measurement, but other units are used in metric systems. In the MKS metric system of measurement, the unit is called the JOULE; a force of 1 newton acting through a distance of 1 meter does 1 joule of work. In the CGS system, the unit is the ERG; a force of 1 dyne acting through a distance of 1 centimeter does 1 erg of work. As may be seen, the erg is very much smaller than the joule and the joule is somewhat smaller than the foot-pound. One erg is equal to 10^{-7} joule, and 1 joule is equal to 0.737 foot-pound.

Torque

Although torque is not a form of mechanical energy, we had better give it some thought right now because it is so often confused with work. Torque is a turning EFFORT—that is, it is the application of a force to try to effect a turning motion. Notice that word TRY. Torque has still been developed even if no turning motion results. It should be clear, then, that torque is not work, since work is done only when the application of a force moves an object through a distance. When we apply a force to try to effect a turning motion, torque is developed WHETHER OR NOT the turning effort results in any movement.

Why do people get torque and work mixed up? Probably because work equals force times distance and torque equals force times distance. The important thing to understand, however, is that the word “distance” has a different meaning for torque than it does for work. When we say that work equals force times distance, the distance is the distance the object is moved. When we say that torque equals force times distance, the distance we are talking about is the LENGTH OF THE MOMENT ARM.

What is a moment arm? It is the distance from the axis of rotation, measured at right angles to the direction in which the force is applied. Suppose, for example, that you take a wrench with an 18-inch handle and apply a 50-pound force in an effort to turn a shaft. The moment arm in this case is 1.5 feet—that is, the moment arm is the distance from the axis of rotation, measured at right angles to the direction of the application of the force. If the shaft refuses to move at all, and if the wrench does not slip, how much torque has been developed? How much work has been done?

Since the shaft has not moved at all, no work has been done. (Work = force $\times$ distance; work = 50×0 ; work = 0 foot-pounds.)

Since you have applied a force of 50 pounds with a moment arm of 1.5 feet, the amount of torque developed is 75 pound-feet. (Torque = force $\times$ moment arm; torque 50×1.5 ; torque 75 pound-feet.)

The correct way to distinguish between torque and work is to express torque in POUND-Feet, OUNCE-INCHES, or similar units, while reserving foot-pounds and other units of this type for the expression of work. If everybody used these units correctly, we would not have too much trouble distinguishing between torque and work. However, the units are often confused, and you will probably see torque expressed in foot-pounds about as often as you'll see it expressed in pound-feet. This leaves it up to you to figure out whether the distance involved is the distance through which an object is moved (work) or whether the distance is the length of the moment arm (torque).

There is more to this problem than just the matter of words or terminology. Pound-feet and foot-pounds are NOT convertible. In the previous example, you applied a force of 50 pounds with a moment arm of 1.5 feet, and produced zero motion of the shaft. Now suppose you apply the same 50-pound force with the same moment arm of 1.5 feet—but this time the end of the wrench handle moves 3 inches (0.25 foot). How much torque has been developed? How much work has been done?

Since you have applied a force of 50 pounds with a moment arm of 1.5 feet, the amount of torque developed is 75 pound-feet. This is exactly the same as the torque developed when NO movement occurred.

Since you have applied a force of 50 pounds and caused the end of the wrench handle to move 0.25 feet, 12.5 foot-pounds of work have been done. (Work = force $\times$ distance; work = 50×0.25 = 12.5 foot-pounds.)

In this example, then, the torque is 75 pound-feet and the work is 12.5 foot-pounds. Clearly, pound-feet and foot-pounds are not the same thing.

The distinction between torque and work can be of considerable importance when you are dealing with certain kinds of instruments. So keep the distinction clearly in mind, and be sure to use the units correctly.

Power

The amount of work done has nothing to do with how long it takes to do it. If you move a weight of 1 pound through a distance of 1 foot, you have done 1 foot-pound of work, and it doesn't matter whether you do it in 1 second or in 1 hour. The RATE at which work is done is called POWER. The common unit of measurement for power is the HORSEPOWER (hp). By definition, 1 horsepower is equal to 33,000 foot-pounds of work per minute or 550 foot-pounds of work per second. Thus a machine capable of doing 550 foot-pounds of work per second is said to be a 1-horsepower machine.

THERMAL ENERGY

All substances are composed of very small particles called molecules. The energy associated with molecules is called thermal energy. Thermal energy, like mechanical energy, exists in two stored forms and in one transitional form. The stored forms of energy are called (1) internal potential energy, and (2) internal kinetic energy. Thermal energy in transition is called heat.

Although molecules are too small to be seen, they behave in some ways pretty much like the larger objects we considered in the discussion of mechanical energy. Molecules have energy of position (internal potential energy) because of the forces which attract molecules to each other. In this way, they are somewhat like a rock and the earth we considered before. Molecules have energy of motion (internal kinetic energy) because they are constantly in motion. Thus the two stored forms of thermal energy are in some ways similar to the two stored forms of mechanical energy, except that everything is on a smaller scale.

Although the term may be unfamiliar to you, you probably know more about internal energy than you realize. Because molecules are constantly in motion, they exert a pressure on the walls of the pipe, cylinder, or other object in which they are contained. Also, the temperature of any substance arises from and is proportional to the activity of the molecules. Therefore every time you read a pressure gage or a thermometer you are finding out something about the amount of internal energy contained in the substance. High pressures and temperatures indicate that the molecules are moving rapidly.

that the substance therefore has a lot of internal energy.

HEAT is a more familiar term than internal energy, yet one that may actually be more difficult to define. The important thing to remember is that heat is THERMAL ENERGY IN TRANSITION. Heat, like work, is a transitory form of energy that exists only between stored forms of energy.

An example may help to illustrate the difference between heat and internal energy. Suppose there are two equal lengths of pipe, made of the same material and containing steam at the same pressure and temperature. One pipe is well insulated; the other is not insulated at all. From everyday experience you know that more heat will flow from the uninsulated pipe than from the insulated pipe. When the two pipes are first filled with steam, the steam in one pipe contains exactly as much internal energy as the steam in the other pipe. We know this is true because the two pipes contain equal volumes of steam at the same pressure and at the same temperature. After a few minutes, the steam in the uninsulated pipe will contain much less internal energy than the steam in the insulated pipe, as we can tell by reading the pressure and temperature gages. What has happened? Stored thermal energy—internal energy—has moved from one place to another, first from the steam to the pipe and then from the pipe to the air. The MOVEMENT or FLOW of thermal energy is properly called heat.

Units of Thermal Energy

Heat and internal energy are measured in the unit called the British thermal unit (Btu) or in the unit called the calorie (cal). Originally, 1 Btu was defined as the amount of heat required to raise the temperature of 1 pound of water through 1 degree Fahrenheit, and 1 calorie was defined as the amount of heat required to raise the temperature of 1 gram of water through 1 degree on the Celsius scale.

The Btu and the calorie are still in use, but the original definitions have been abandoned by international agreement. The Btu and the calorie are now defined in terms of the joule. By definition, 1 Btu is equal to 1054.886 joules, and 1 calorie is equal to 4.18605 joules. As may be seen, the Btu is a much larger unit than the calorie; 1 Btu is equal to approximately 252 calories.

When large amounts of thermal energy are involved, it is often more convenient to use multi-

ples of the Btu or the calorie. For example, the unit kB is used for 1000 Btu, and the unit mB is used for 1,000,000 Btu. Similarly, the kilocalorie may be used to express calories in thousands; 1 kilocalorie is equal to 1000 calories. The kilocalorie, also called the "large calorie," is the unit normally used to indicate the thermal energies of various foods. Thus a portion of food that contains "100 calories" actually contains 100 kilocalories or 100,000 ordinary calories.

Heat Transfer

Heat can flow from one substance to another ONLY when a temperature difference exists. Heat flows ONLY from a higher temperature to a lower temperature. When two objects at different temperatures are placed in contact with each other (or near each other) heat flows from the warmer object to the cooler one until both are at the same temperature. Heat transfer occurs at a faster rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat transfer approaches zero.

Conduction, radiation, and convection are usually considered to be the three methods by which heat transfer can occur. It is more accurate, however, to consider conduction and radiation as the two basic methods of heat transfer and to consider convection separately as a special process which involves movement within a mass fluid.

CONDUCTION is the method by which heat flows from a hotter to a colder substance when there is physical contact between the two substances. For example, consider a cold metal bar that is held firmly against a piece of red-hot metal. In a short time, the end of the bar which is not touching the hotter metal will have become too hot to hold. We say that heat has been CONDUCTED from molecule to molecule through the entire bar. The process of conduction will continue as long as there is a temperature difference between the two ends of the bar.

RADIATION is a mode of heat transfer, via electromagnetic waves, that does not involve any physical contact between the hotter object and the cooler object. A person sitting near a hot stove is warmed by thermal radiation from the stove, even though the air between remains relatively cold. Thermal radiation passes through any transparent substance—air, glass, ice—without warming it to any extent because

transparent substances are very poor absorbers of radiant energy.

When radiant energy falls upon a body or substance that can absorb it, some of the energy is absorbed and some is reflected. The amount absorbed and the amount reflected depend in large part upon the surface of the receiving body or substance. Dark, opaque bodies absorb more thermal radiation than shiny, white, bright or polished bodies. Shiny, bright, white, or polished bodies reflect more thermal radiation than dark, opaque bodies. Good radiators are also good absorbers, and poor radiators are poor absorbers. In general, good reflectors are poor radiators and poor absorbers.

CONVECTION is often loosely classified as a form of heat transfer. However, it is "heat transfer" in quite a different way than the basic heat transfer processes of conduction and radiation. Convection is the movement of a mass of fluid (liquid or gas). As this movement occurs, the moving portions of the fluid transfer their contained thermal energy from one part of the fluid to another. The effect of convection is thus to mix the various portions of the fluid. As this mixing takes place, heat transfer occurs from one part of the fluid to another and between the fluid and its surroundings. But this heat transfer, like any other heat transfer, takes place by conduction and by radiation. In other words, convection transports portions of the fluid; conduction and radiation transfer the thermal energy.

What causes convection? In case of natural convection, the movement of the fluid is caused by differences in density of different parts of the fluid. The differences in density are usually caused by unequal temperatures within the mass of fluid. For example, as the air over a hot radiator is heated, it becomes less dense and therefore begins to rise. Cooler, heavier air is drawn in to replace the heated air, and convection currents are thus set up. In the case of forced convection, some mechanical device such as a pump or a fan produces movement of the fluid.

Sensible Heat and Latent Heat

The terms sensible heat and latent heat are often used to indicate the effect that the flow of heat has on a substance. The flow of heat from one substance to another is normally reflected in a temperature change in each substance, with the hotter object becoming cooler and the cooler object becoming warmer. However, the flow of

heat is NOT reflected in a temperature change in a substance that is in process of changing from one physical state to another. When the flow of heat is reflected in a temperature change, we say that sensible heat has been added to or removed from the substance. When the flow of heat is not reflected in a temperature change but is reflected in the changing physical state of the substance, we say that latent heat has been added or removed.

The three basic physical states of all matter are solid, liquid, and gas (or vapor). The physical state of a substance is closely related to the distance between molecules. In general, molecules are closest together in solids, farther apart in liquids, and farthest apart in gases. When the flow of heat to a substance is not reflected in a temperature change, we know that the energy is being used to increase the distance between the molecules of the substance and thus change it from a solid to a liquid or from a liquid to a gas. You might say that latent heat is the energy price that must be paid for a change of state from solid to liquid or from liquid to gas. The energy is not lost; rather, it is stored in the substance as internal energy. The energy price is "repaid," so to speak, when the substance changes back from gas to liquid or from liquid to solid, since heat flows FROM the substance during these changes of state.

Sensible heat and latent heat are not really different forms of heat; the terms are used merely to indicate the different kinds of EFFECTS that can be produced by the flow of heat.

Latent heat is often identified in such a way as to indicate the change of state involved. The heat required to change a liquid to a gas is called the latent heat of vaporization. The heat that is given off when a gas changes to a liquid is called the latent heat of condensation. (Of course, the latent heat of vaporization and the latent heat of condensation are exactly the same numerically.) The heat that is required to change a solid to a liquid (and also the heat that is given off when a liquid changes to a solid) is called the latent heat of fusion.

The amount of heat required to cause a change of state (or, on the other hand, the amount of heat given off during a change of state) varies according to the pressure at which the process takes place.

Thermal Properties of Matter

In studying about various kinds of instruments, you will come across the terms "thermal

conductivity," "specific heat," and "coefficient of expansion." In general, we may regard these as thermal properties or thermal characteristics that are different for each material or substance.

THERMAL CONDUCTIVITY is different for each material or substance and must therefore be determined experimentally for various materials. Each material has its own "coefficient of thermal conductivity" that indicates the rate at which this particular material will CONDUCT thermal energy. The coefficient of thermal conductivity indicates the quantity of heat that will flow through unit cross section and unit length of a material in unit time when there is unit temperature difference between the hotter and the colder faces of the material.

SPECIFIC HEAT is, like thermal conductivity, a thermal property of matter that must be determined experimentally for each substance. In general, we may say that specific heat is the property of matter that explains why the addition of equal quantities of heat to two different substances will not necessarily produce the same temperature rise in the two substances. Specific heat is defined as the quantity of heat required to raise the temperature of unit mass of the substance 1 degree. In the metric CGS system, specific heat is expressed in calories per gram per degree Celsius. In the metric MKS system, it is expressed in kilocalories per kilogram per degree Celsius. In British systems, it is expressed in Btu per pound per degree Fahrenheit. The specific heat of water is 1.00 in any system. The numerical value of specific heat for any given substance is the same in all systems of measurement; however, the units are of course different.

The specific heat of a substance is different when the substance is in one physical state than when it is in another physical state. For example, the specific heat of water (in the liquid form) is 1.00, but the specific heat of ice (which is water in the solid form) is about 0.48. This means that it takes almost twice as much heat to raise liquid water 1 degree as it does to raise an equal quantity of ice 1 degree.

Specific heat varies according to the pressure, volume, and temperature. Specific heat values for solids and liquids are obtained while the substance is kept at constant pressure. The specific heat of any gas may vary tremendously. The specific heat of a gas is given either as specific heat at constant volume or as specific heat at constant pressure.

COEFFICIENTS OF EXPANSION may be either linear or volumetric (cubic). The coefficient of LINEAR expansion is the change in length per unit length per degree of change in temperature. The coefficient of VOLUME expansion is the change in volume per unit volume per degree of change in temperature. If you think about these definitions, you will see that the numerical value of a coefficient of expansion is independent of the units of length or volume but is NOT independent of the temperature scale. For example, the coefficient of linear expansion of aluminum is 0.000022 per °C but 0.000012 per °F. Both linear and volumetric coefficients of expansion are different for different materials; this fact is utilized in the design of bi-metallic thermometers and other measuring devices.

ENERGY CONVERSIONS

The utilization of energy frequently requires that energy be converted from one form to another. In studying measuring devices, you will find many examples of energy conversions or transformations. For example, consider a distant-reading thermometer that consists of a bulb, a capillary tube, and a Bourdon tube, all filled with mercury. When the temperature increases, thermal energy (heat) flows to the bulb. The mercury expands, and an increased pressure is transmitted through the capillary tubing to the Bourdon tube. As the Bourdon tube moves, work is done. The input is thermal energy and the output is mechanical energy. Disregarding friction losses, the input of one form of energy is equal to the output of the other form of energy.

The energy output may be quite different from the energy input, but the TOTAL AMOUNT of energy input must always equal the total amount of energy output. This last sentence is perhaps the simplest way of stating the PRINCIPLE OF THE CONSERVATION OF ENERGY. The principle may also be stated as "Energy can be neither created nor destroyed, but only transformed," or as "The total quantity of energy in the universe is always the same." But the simplest way to remember it is just "Energy in must equal energy out."

The energy transformation by which thermal energy is converted into mechanical energy in the form of useful work is one of the commonest ways in which we utilize energy, but it is by no means the only way. Just look around and see how many energy conversions you can find. Is

something burning? Chemical energy is being converted into thermal energy. Is a light bulb giving out light? Electrical energy is being converted into light and other electromagnetic forms of energy. If the electricity is coming from a steam-driven turbogenerator, the electrical energy is the result of a transformation of chemical energy (combustion of a fuel) to thermal energy (heat) to mechanical energy (work) to electrical energy.

Many energy conversions are useful, but some are not. When energy is transformed into a form of energy that we cannot use, we say there has been an "energy loss." This is rather a careless way of speaking, of course, because energy cannot be lost or destroyed; it can only be transformed. But some transformations result in energy losses as far as our own particular needs are concerned. One of the commonest examples of an energy loss is the loss that occurs when work (mechanical energy) is transformed into heat (thermal energy). This loss (often referred to as a friction loss) occurs in all machines, instruments, and other devices that have moving parts. The friction loss may be very large, as in the case of a rough object being dragged across a rough surface, or it may be very small, as in the case of a pointer moving in a precision-built pressure gage. But as long as we have moving parts, we will have some friction loss.

BEHAVIOR OF MATTER

To understand how and why measuring devices work, it is necessary to understand something about the behavior of matter in its various phases or states. The following sections deal with certain aspects of the behavior of solids, liquids, and gases. Only information that is particularly related to instrumentation is included here; for additional information on the properties, characteristics, and behavior of matter, consult any physics textbook.

SOLIDS

When an external force is applied to a solid material, the material is subjected to stresses and is always strained to some extent. Although the two terms are often used as though they meant the same thing, stress and strain have different meanings. STRESS is the amount of internal force with which a material resists a change in shape. STRAIN is the deformation or

change in shape that is caused by an applied load. For example, a length of pipe supported on each end will sag or bow unless the internal force within the material is great enough to resist the change. The external force is, in this case, the force of gravity acting upon the weight of the pipe. The internal force by which the pipe is kept rigid and straight is called stress. When the internal stress is not great enough to keep the pipe from sagging, a noticeable change occurs in the shape and dimensions of the pipe. This change is called strain. Some strain ALWAYS occurs as a reaction to stress, even if the change in shape and dimensions is so small as to be almost unmeasurable.

Stress is not the same thing as load. The load is the external applied force, while the stress is the internal force with which the material resists the applied force. However, stress and load are measured in the same units: pounds per square inch, pounds per square foot, or similar units.

Stress occurs because molecular forces within the material resist the change of shape that an applied load tends to produce. In other words, stress results from the resistance of the molecules to being shifted around, pulled apart, or squeezed together. Because stress involves molecular forces, a material that is subjected to a load develops an enormous number of stresses, rather than just one stress. For the sake of simplicity, however, we often speak of stress as if it is one internal force, acting in the direction opposite to the direction of the applied load. In other words, we consider the total effect of all the individual molecular stresses, rather than trying to consider each molecular stress separately.

The manner in which the load is applied determines the type of stress that will develop. Applied forces are usually considered as being of three different kinds: tension (or tensile) forces, compression forces, and shearing forces. The basic stresses, therefore, are also tension (or tensile) stresses, compression stresses, and shearing stresses. Complex stresses such as bending stresses and torsional stresses are combinations of two or more of the basic types.

Tension stresses are developed when a material is subjected to a force that tends to pull the material apart. If a cable is fastened to the overhead and a weight is attached to the free end, tension stresses are developed within the cable. These tension stresses resist the tension forces

that tend to put the cable apart. (Even if you can't see it, some strain is also occurring in this situation.)

Compression stresses develop within a material to oppose the forces that tend to compress or crush the material. A column that supports an overhead weight is said to be in compression, and the internal stresses that develop within the column are compression stresses.

Shearing stresses are developed within a material when opposite external forces are applied along parallel lines in such a way as to tend to cut the material. Shearing forces tend to separate material by sliding part of the material in one direction and the rest of the material in the opposite direction. The action of a pair of scissors is an example of shear forces and shear stresses. The scissors apply shear forces and the material being cut resists the shear forces by its internal shear stresses. Forces tending to produce shear in a rivet are illustrated in figure 4-1.

Bending stresses develop when a material is subjected to external forces that tend to bend it. When a load is applied to a beam, for example, as shown in figure 4-2, the upper surface is in compression and the lower surface is in tension. The neutral axis, indicated by the broken line in figure 4-2, is neither in compression nor in tension.

Torsional stresses are developed in a material when external forces are applied in such a way that they tend to produce rotation. For example, the pointer shaft in an instrument rotates when the external applied forces are greater than the internal torsional stresses developed in the shaft. Torsional stress is primarily a special form of shear stress, although it may also involve some compression stress and some tension stress.

As we have seen, a deformation or change of shape (strain) occurs when a material is subjected to external forces that cause stresses

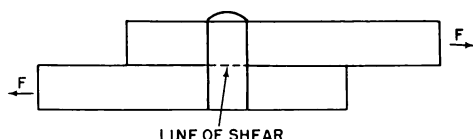


Figure 4-1—Shearing forces applied to a rivet.

11.25

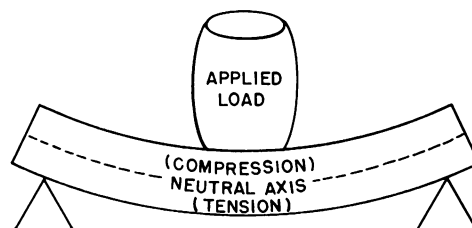


Figure 4-2.—Load applied to a beam.

11.26

in the material. The ability of a material to return to its original size and shape after strain is the property known as **ELASTICITY**.

All materials are elastic to some extent. It may surprise you to learn that a piece of steel is more elastic than a rubber band. The rubber band stretches more than the steel, since it is more easily strained. But the steel returns more nearly to its original shape and size, and is therefore more truly elastic.

The greatest stress which a material is capable of withstanding without taking a permanent set (that is, without becoming permanently deformed) is known as the **ELASTIC LIMIT**. Below the elastic limit, **THE AMOUNT OF STRAIN IS DIRECTLY PROPORTIONAL TO THE AMOUNT OF STRESS** (Hooke's Law). Above the elastic limit, however, the amount of strain that results from an increase in load (and therefore an increase in stress) is way out of proportion to the increase in load.

Strain may be axial, angular, or both, depending upon the nature of the applied load and the nature of the stresses that are developed within the material to withstand the applied load. When the elastic limit is exceeded through the application of an axial load, the material will be permanently deformed either by elongation or by compression. When the applied load is not axial (as in shear and torsion) the resulting strain is angular and, if permanent deformation results, the deformation is also angular.

As previously noted, the amount of strain is proportional to the amount of stress up to (or almost up to) the elastic limit. The ratio of stress to strain is therefore a constant for each material. This constant, which is called the **MODULUS OF ELASTICITY**, is obtained by dividing the stress by the elongation caused by that stress. For example, suppose that a certain material is so loaded that the internal stress developed in tension is 30,000 psi, and that with

this stress the material elongates 0.0015 inch per inch. The modulus of elasticity of this material is 30,000 psi divided by 0.0015 inch per inch, or 20,000,000 psi per inch of elongation per inch of length.

The modulus of elasticity is often used to determine the amount of elongation that will occur when a given stress is developed in a material. For this purpose, you divide the stress by the modulus of elasticity in order to obtain the elongation that will occur.

Obviously, elasticity is a primary requirement for a spring. In fact, a spring is defined as any elastic material in which strain is directly proportional to the applied force, up to (or almost up to) the elastic limit of the material. The springs used in instruments come in such a great variety of shapes that some of them can hardly be recognized as springs; but they all have one thing in common, and that is the fact that they are elastic in the true sense of the term.

Strength is the property of a solid that enables the material to resist deformation. **ULTIMATE STRENGTH** is the maximum stress that a material is capable of withstanding in tension, compression, or shear before it breaks. The ultimate strength that is most important for many metals is **TENSILE STRENGTH**, or the ultimate strength of the material in tension.

Some materials are equally strong in tension, compression, and shear. However, many materials show marked differences. The types of loading (tension, compression, or shear) is therefore specified when the ultimate strength is given.

If a material is stressed repeatedly in a cyclical manner, it will probably fail at a loading that is considerably below its ultimate strength in tension, compression, or shear. For example, you can break a thin steel rod with your hands after the rod has been bent back and forth several times in the same place, even though you could not break an identical rod that had not previously been stressed. The tendency of a material to fail after repeated stressing at the same point is called **FATIGUE**. Fatigue is often the cause of failure of small metal parts or metal tools such as screwdrivers.

LIQUIDS

A solid substance becomes liquid when the temperature is increased to the melting point for that particular substance. The increased

temperature causes an increase in the internal kinetic energy of the molecules, and this increased energy allows the molecules to move more freely, overcoming some of the forces that, in the solid state, bind the molecules into an orderly and rigid structure. In a liquid, the molecules are free to move and to slide over each other. It is for this reason that a liquid flows. It is also for this reason that a liquid has no shape of its own but takes the shape of whatever container it is in.

Although the forces of attraction between molecules are weaker in a liquid than in a solid, these forces are still great enough to keep the molecules from flying off into the space above the surface of the liquid. In other words, there are still strong enough forces of attraction between the molecules to hold the liquid together. It is for this reason that a liquid, unlike a gas, has a definite free surface and therefore a definite volume. The strength of the molecular forces has a direct bearing on several characteristics of liquids that are important in instrumentation.

COHESION is the name for the force of attraction between like molecules, and **ADHESION** is the name for the force of attraction between unlike molecules. If you try to pour honey, molasses, ketchup, or some other viscous liquid, you will see the forces of **COHESION** at work, trying to keep the molecules of the liquid together. If you dip a glass rod into water and then remove it, you will see the forces of **ADHESION** at work as some of the water clings to the glass. But if you dry this same glass rod, dip it into mercury, and then remove it, you will not find any mercury clinging to the glass. Why this difference? Water wets the glass because the adhesion of the water molecules to the glass is greater than the cohesion between the water molecules. Mercury does not wet the glass because the forces of cohesion are greater than the forces of adhesion. It should be clear that the forces of cohesion and adhesion differ from one liquid to another.

The free surface of a liquid differs from the rest of the liquid in that the molecules at the surface are under unequal tension. A molecule of liquid that is fully submerged is acted upon equally in all directions by the cohesive forces of the surrounding molecules. But a molecule at the surface of a liquid is acted upon by sidewise forces and by downward forces, but not by upward forces. The unbalance of forces causes the molecules at the surface of the liquid to

contract and form a layer that acts like an elastic film. This tendency of the surface layer of molecules to contract because of unbalanced forces is called **SURFACE TENSION**. You can demonstrate surface tension by allowing a container of water to become very still and then very carefully placing a needle on the surface of the water. If you do this carefully enough, the needle will stay on the surface of the water instead of sinking. The needle is not floating, since it is not buoyed up by the water; rather, the needle is merely resting on the surface film formed by the contraction of the top layer of molecules. If anything disturbs this film, the needle will plunge to the bottom of the container.

Since a sphere has the smallest surface area for any given volume, surface tension tends to cause a spherical shape in any free liquid that is not acted upon by other forces. Raindrops are spherical except for the elongation that is produced by the force of gravity. A small drop of mercury on a table is spherical except for a slight flattening at the bottom.

A liquid in a container does not have a precisely level surface. If you look carefully at water in a glass tube and at mercury in a similar tube, as shown in figure 4-3, you will see that the surface of the water is slightly concave and the surface of the mercury is slightly convex. Liquids that wet the glass tube (that is, liquids in which the forces of adhesion are greater than

the forces of cohesion) have concave surfaces. Liquids that do not wet the tube (that is, liquids in which the forces of cohesion are greater than the forces of adhesion) have convex surfaces. When the forces of adhesion are greatest, the surface of the liquid is lifted up slightly around the edge; when the forces of cohesion are greatest, the surface is slightly depressed around the edge. The curving surface of a liquid is called the **MENISCUS**, no matter whether the curve is concave or convex.

The fact that a liquid surface is either concave or convex must be taken into account when reading thermometers, manometers, gage glasses, or other measuring devices that make use of a liquid surface. Readings must always be taken from the center of the meniscus; this means that you take the reading at the **LOWEST** point of the meniscus for liquids that behave like water but at the **HIGHEST** point of the meniscus for liquids that behave like mercury.

The term **CAPILLARITY** refers to the tendency of a liquid to rise higher than normal or to be depressed below normal in a capillary tube. A capillary tube is any tube of very small diameter. Liquids that wet the tube, such as water, rise higher in a capillary tube than they would in a larger tube, given the same pressure, temperature, and other conditions. Liquids that do not wet the tube, such as mercury, do not rise as high in a capillary tube as they would in a larger tube, given the same conditions. This particular behavior of liquids is related to surface tension, cohesion, and adhesion; it is obviously of considerable significance in the design of certain types of instruments.

Up to this point, we have looked at the behavior of liquids from the molecular point of view. Now let's consider the behavior of liquids in larger quantities, with particular reference to the application and transmission of forces in liquids. In other words, let's talk about **HYDRAULICS**, the branch of science that deals with the practical application of water or other liquids in motion. The information given here is merely an introduction; for further information on hydraulics, consult Fluid Power, NavPers 16193-A.

Even under extreme pressure, liquids cannot be compressed very much. A pressure of 100 psi applied to a body of water reduces the volume by only about 3/10,000 of the original volume. Other liquids are similarly incompressible. In a very few hydraulic systems, some allowance must be made in the design of the system for

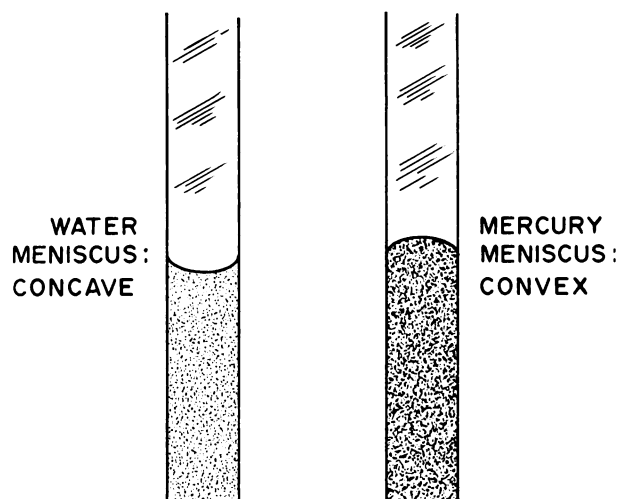


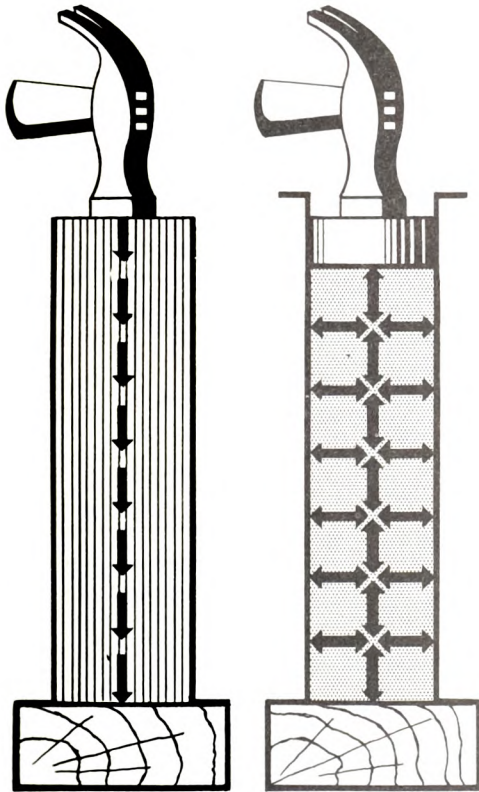
Figure 4-3.—Meniscus of water and meniscus of mercury.

61.115

the slight compression of liquid; but in general we may say that liquids are incompressible for most practical purposes.

Because of the incompressibility of liquids, the transmission of forces through a liquid has certain distinct characteristics. When we strike the end of a rigid bar, the main force of the blow is carried straight through to the other end. This happens because the bar is rigid. The direction of the blow almost entirely determines the direction of the transmitted force. The more rigid the bar, the less force is lost inside the bar or transmitted outward at right angles to the direction of the blow.

But when we apply pressure to the end of a column of confined liquid, the pressure is transmitted not only straight through to the other end but also equally and undiminished in every direction. Figure 4-4 illustrates the difference between pressure applied to a rigid bar and pressure applied to a column of contained liquid.



5.180

Figure 4-4.—Results of pressure applied to a rigid bar (left) and to a column of liquid (right).

The principle that pressure is transmitted equally and undiminished in all directions through a contained liquid is known as PASCAL'S PRINCIPLE. This principle may be regarded as the basic law or foundation of the science of hydraulics.

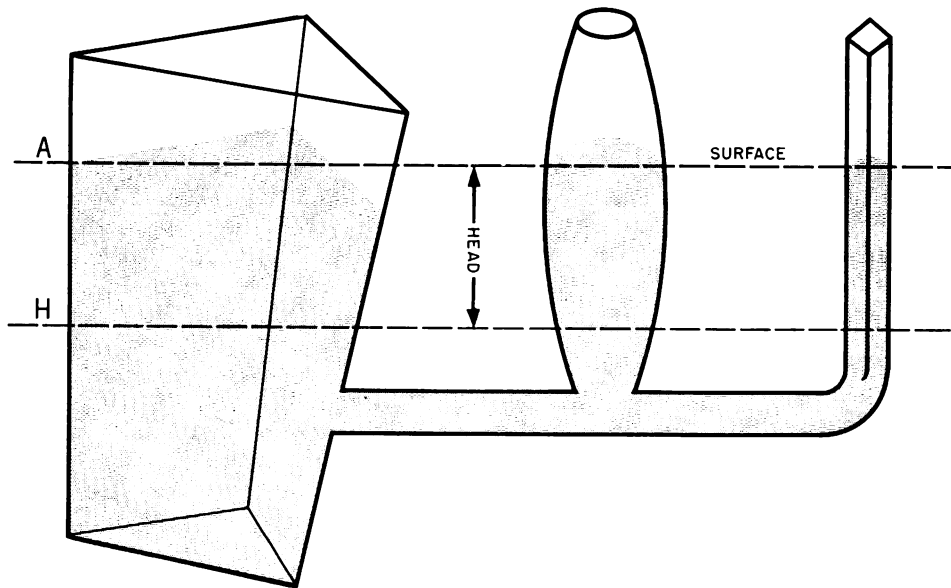
An important corollary of Pascal's principle is that the transmission of pressure through a liquid is not altered by the shape of the container. This idea is illustrated in figure 4-5. If the pressure due to the weight of the liquid is 8 psi at any one point on the horizontal line H, it is 8 psi at EVERY point along line H. The pressure due to the weight of the liquid at any level thus depends upon the vertical distance from the chosen level to the surface of the liquid. The vertical distance between two horizontal levels in a liquid is known as the HEAD of the liquid. The head effect is the pressure produced by the head or vertical distance times the density of the fluid.

We have already defined pressure as FORCE PER UNIT AREA. We may turn this around and say that force is equal to pressure times area. Figure 4-6 shows how a force of 20 pounds acting on a piston with an area of 2 square inches can produce a force of 200 pounds on a piston with an area of 20 square inches. The system would, of course, work the same in reverse. If we consider piston 2 as the input piston and piston 1 as the output piston, then the output force would be 1/10 the input force.

This leads to a general rule: If two pistons are used in a hydraulic system, the force acting on each piston will be directly proportional to its area, and the magnitude of each force will be the product of the pressure and the area.

The second basic rule for two pistons in a hydraulic system such as the one shown in figure 4-6 may be stated as follows: The distance moved by each piston is inversely proportional to the area of the piston. Thus if piston 1 in figure 4-6 is pushed down 1 inch, piston 2 will be raised 1/10 of an inch.

If you think about these two basic rules, you will be able to derive another basic rule: The input force multiplied by the distance through which it moves is exactly equal to the output force multiplied by the distance through which it moves, disregarding any energy losses due to friction. Does this statement sound familiar? It's just another statement of the principle of the conservation of energy: Energy in = Energy out.



147.105

Figure 4-5.—Pressure in liquid is not affected by shape of container.

Some hydraulic systems are very simple, some are very complex. But almost any hydraulic system, simple or complex, can be traced out and understood if you remember the basic laws and principles of hydraulics.

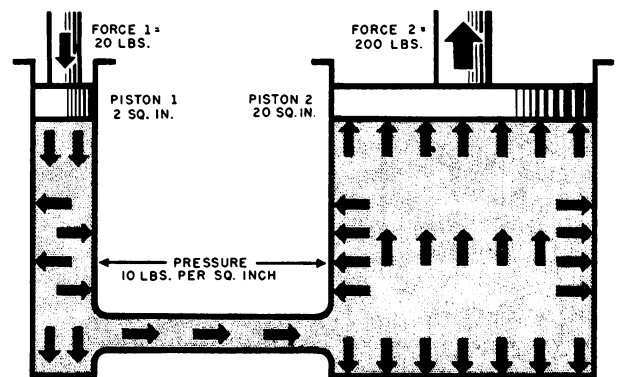
GASES

If we raise the temperature of a liquid to its vaporization point, we increase the kinetic energy of the molecules to such an extent that some molecules are able to escape the liquid—that is, they fly off from the liquid and then exist as molecules of gas. If we continue to supply heat, all of the liquid will eventually be vaporized or turned into gas. It is apparent, therefore, that the molecules of a gas are at a higher level of internal kinetic energy than the molecules of a liquid.

The pressure, temperature, and volume relationships that hold true for gases may be summarized as follows:

1. When the temperature is held constant, increasing the pressure (absolute) on a gas causes a proportional decrease in volume. Decreasing the pressure (absolute) causes a proportional increase in volume. This is known as Boyle's Law.

2. When the pressure is held constant, increasing the absolute temperature of a gas causes a proportional increase in volume. Decreasing the absolute temperature causes a proportional decrease in volume. When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure. Decreasing the temperature causes a proportional decrease in pressure. This is known as Charles' Law.



4.7

Figure 4-6.—Relationship of force, pressure, and area in simple hydraulic system.

These laws may be combined into the statement that, for a given weight of any gas, the product of the absolute pressure and the volume, divided by the absolute temperature, is a constant. Or, in equation form,

$$\frac{pV}{T} = \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} = R$$

where

p = absolute pressure

V = total volume

T = absolute temperature

R = the gas constant

The relationships expressed above hold for the so-called ideal or perfect gases. An ideal gas may be defined as a gas that consists of infinitely small molecules that exert no forces on each other. Although the laws of ideal gases were developed on the basis of experiments made with air and other real gases, later experiments

showed that these relationships do not hold precisely for real gases over the entire range of pressures and temperatures. However, air and other gases may be treated as ideal gases over quite a wide range of pressures and temperatures without any great amount of error. Values of the gas constant for some common gases are:

Air	53.3
Oxygen	48.3
Nitrogen	55.0
Hydrogen	766.0
Helium	386.0

Forces are transmitted through gases in much the same way as they are through liquids, except for differences caused by the fact that a gas is compressible and a liquid is not compressible. Because the gas is compressible, it provides a much less rigid medium for the transmission of force; this is the main difference between the action of liquids and the action of gases in fluid power systems.

CHAPTER 5

PRESSURE GAGES

Pressure is one of the most commonly measured variables. It is an important variable for its own sake and it is also important as a measure of other variables. Any device that responds to pressure is called a pressure-sensitive or a pressure-sensing device. Any pressure-sensitive that is actuated by pressure and then supplies power or a signal for the measurement or control of some other variable is generally called a pressure transducer. (Note: the term transmitter is used occasionally, in accordance with specifications.) In a general sort of way, all pressure-sensitive devices and pressure transmitters (electrical, pneumatic, and hydraulic), as well as transducers, are often referred to quite simply as pressure gages or indicators; this usage is not objectionable provided we understand the correct terminology and use it when necessary.

Pressure gages may be classified in a number of different ways. Sometimes they are classified according to use; for example, we refer to steam gages, hydraulic gages, refrigeration gages, and so forth, according to the application. Sometimes pressure gages are classified according to manufacturer; this is particularly true in cases where some special design of gage becomes associated with a certain manufacturer. Pressure gages may also be classified according to the general type of measuring action; by this classification we have such categories as force balance gages, position balance gages, torque balance gages, and so forth.

The classifications mentioned are used in industry. The Navy, however, classifies gages on the basis of liquid, gas, and oxygen services, caisson gages, vertical scale, internal light miniature designs, low pressure ranges (100 psi or below), and ambient pressure isolated sensor where the dial resembles a Bourdon tube gage and the sensor a barometer.

Perhaps the simplest way to classify pressure gages is in accordance with the type of pressure element employed. The basic distinction to be made here is that some pressure elements are mechanical and some are electrical. This chapter deals only with pressure gages that have mechanical pressure elements. There are two main categories of mechanical pressure elements: (1) liquid-column elements, and (2) elastic elements. There are various types of pressure-sensitive elements in each category, as discussed in the following sections. It should be noted that many pressure-sensitive devices and transducers are connected to or included in recording devices.

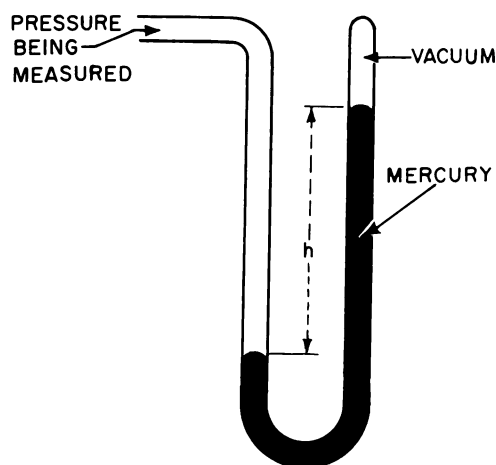
LIQUID-COLUMN ELEMENTS

Liquid-column elements for pressure measurement include the devices commonly referred to as mercurial barometers and manometers. Liquid-column elements are simple, reliable, and accurate. They are used particularly (although not exclusively) for the measurement of relatively low pressures or small pressure differentials. Liquids commonly used in this type of instrument include mercury, water, and alcohol; other liquids having varying specific gravities, may be used for special applications. These liquids are colored for ready identification. The liquid used in any particular instrument depends upon the range of pressures to be measured and the length of the column.

One of the simplest liquid-column elements is the fixed-cistern mercury barometer. This device consists of an open well or cistern which is partially filled with mercury and a calibrated tube which is open to the mercury in the cistern. The tube is evacuated so that there is a vacuum above the mercury in the tube. Atmospheric pressure acts upon the open surface of the mercury in the cistern, thereby pushing the mercury up into the tube. The height of the mercury in the

tube thus gives a direct indication of the existing atmospheric (barometric) pressure. The readings are usually in millimeters of mercury for this type of barometer, but may also be in inches or millbars of mercury.

A simple U-tube liquid-column element for measuring absolute pressure is shown in figure 5-1. The liquid used in this device is mercury. one leg of the U-tube is closed and the other leg is exposed to the absolute pressure being measured. There is a vacuum above the mercury in the closed end. The absolute pressure is equal



147.57

Figure 5-1.—U-tube liquid-column element for measuring absolute pressure.

to the difference in level in the two legs (h) times the density of the liquid. Or, in equation form,

$$P = h d$$

where P = absolute pressure, h = difference in level, and d = density of the liquid. This equation may be regarded as the basic equation for reading any type of liquid-column element. However, some designs require that additional factors be included in the equation.

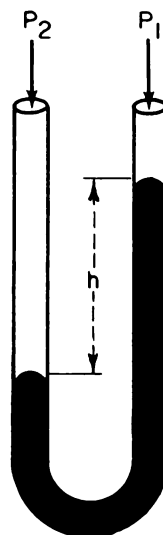
The U-tube liquid-column manometer shown in figure 5-1 is not suitable for the measurement of extremely low absolute pressures. For this purpose a special type of manometer called a McLeod gage is used. There are several designs of the Mc-Leod gage, but they all operate on the same basic principle. A known amount of gas at a very low absolute pressure is compressed into a much smaller volume by the pressure from a

mercury column. The mercury traps the gas in a measuring tube, and the final volume of the compressed gas indicates the absolute pressure.

Figure 5-2 shows a simple U-tube manometer that is used for measuring pressure differentials. The pressure differential is expressed by the equation,

$$P_2 - P_1 = d h$$

where $P_2 - P_1$ is the pressure differential, d is the density of the manometer liquid, and h is the difference in level. As may be seen, this is essentially the same equation as the one previously given, except that we are now interested in finding pressure differential rather than absolute pressure.



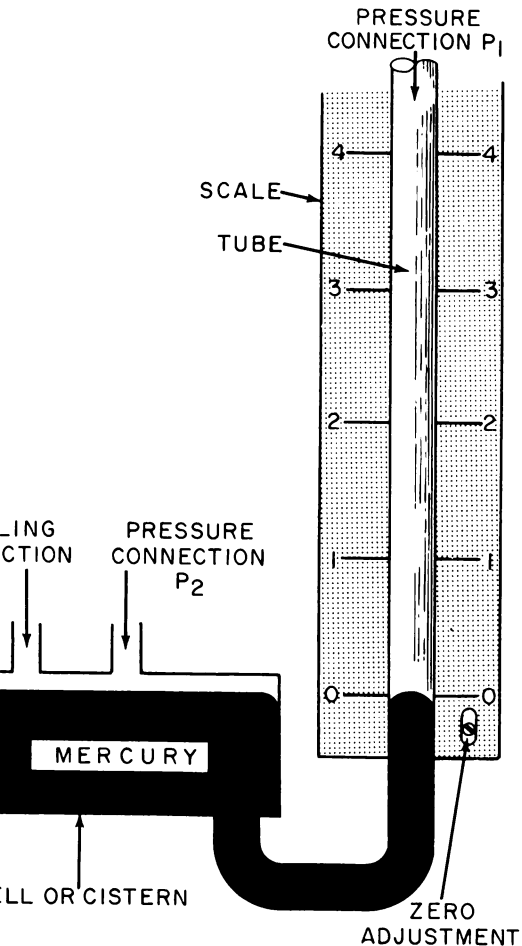
61.4 (61C)A

Figure 5-2.—U-tube manometer for measuring differential pressure.

Figure 5-3 shows a well-type or cistern-type manometer of a type that is commonly used for a variety of applications. The operating principles of this device are, of course, the same as for the simple U-tube manometer; but there are some important differences that should be noted.

Since the cross-sectional area of the well is large in comparison to the cross-sectional area of the tube, the liquid that is forced up into the tube by the applied pressure is a small proportion of the total liquid contained in the system. The liquid level in the well therefore remains

OXIMATELY constant. For applications in great precision is not required, then, it is sufficient to merely read the liquid level in the tube to determine the pressure. When we do this, however, we are ignoring an error that is built into the design of this type of manometer—that we are ignoring the distance between the actual liquid level in the well and the liquid level that is reached after pressure has been applied to the liquid in the well.



61.4 (61C)B

Figure 5-3.—Cistern-type manometer.

Suppose, for example, that the cross-sectional area of the cistern is 10 times the cross-sectional area of the tube bore. If the applied pressure causes the liquid level in the cistern to rise one tenth of an inch, the liquid level in the tube will rise to the 1-inch mark. Does this mean the pressure differential is equal to 1 inch

of mercury? Not at all. When reading a manometer, we should by rights read the DIFFERENCE between the two liquid levels. When we ignore the change in liquid level in the cistern, we are ignoring a slight but persistent error. When the reading on the scale is 1 inch, the difference between the two liquid levels is actually 1 inch PLUS 1/10 of an inch, or a total of 1.1 inches. If the pressure differential increases to the point where the liquid level in the cistern is pushed down 1/10 of an inch, the mercury in the tube will go to the 2-inch mark; but the real difference in levels will be 2.2 inches, rather than 2 inches. And so it goes, up the entire scale. When the mercury in the tube is at a level that gives a 10-inch reading on the scale, the actual difference in the height of the liquid levels is now 11 inches rather than 10 inches. As may be seen, the size of the error becomes increasingly important as the amount of pressure difference increases.

One way of handling this error is to design the manometer in such a way that there is a very great difference between the cross-sectional area of the cistern and the cross-sectional area of the tube bore. When the area of the cistern is very large in relation to the area of the tube bore, the amount of error will be reduced even though it is never entirely eliminated. This solution to the problem is satisfactory, up to a point. But there are limits as to how large the cistern can be, because of space requirements; and there are limits as to how small the tube bore can be, because too small a bore would introduce additional errors caused by capillarity (the elevation or depression of liquids in small diameter tubes).

Another way of handling this error is to change the intervals on the manometer scale in such a way that the scale reading will actually reflect the true difference between the level in the cistern and the level in the tube bore. Since this procedure involves making the "inch marks" slightly less than 1 inch apart, the process is sometimes referred to as "shrinking" the scale.

In many cistern-type manometers, the problem is avoided by using a float that rides on the surface of the liquid in the cistern. The float is attached to a lever that rotates a shaft through a pressure-tight bearing. A pointer, attached to the shaft, moves over a calibrated dial and the pressure (or the pressure differential) may be read directly from the position of the pointer on the dial.

The types of liquid column elements mentioned thus far are among the simplest or the

most commonly used types. A wide variety of other designs are available to suit a number of particular applications. In some designs the U-tube is readily identifiable, as in part A of figure 5-4; in other designs, only one leg of the U-tube is visible, as in part B of figure 5-4. Some U-tubes are designed to be installed vertically (included tube), as shown in the examples given thus far, or they are designed to be inverted at an angle. In many industrial applications, the U-tube is so enlarged that it actually consists of two chambers connected by tubing. There is even one design in which the U-tube is formed into a complete ring or circle.

In spite of all these variations in design, the basic principles of liquid-column elements remain the same. If you understand the principles of even the simplest U-tube manometer, you should be able to figure out the operating principles of any liquid-column element.

ELASTIC ELEMENTS

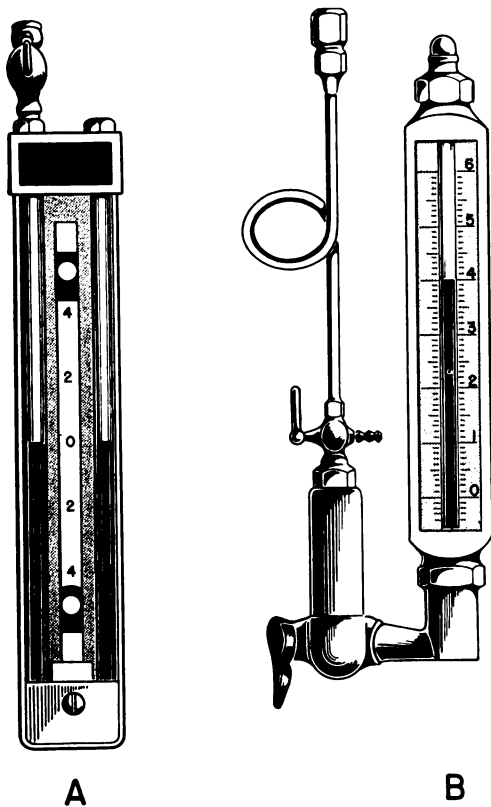
Elastic elements used for pressure measurement include Bourdon elastic elements, bellows elastic elements, and diaphragm elastic elements. All three types of elastic elements are suitable for use in pressure gages, vacuum gages, and compound (both pressure and vacuum) gages. Bourdon elements are suitable for the measurement of very high pressures, up to about 100,000 psig. The upper limit for bellows elements (sensing) is about 800 psig and for diaphragm elements about 400 psig. Diaphragm elements and bellows elements (sensing) are commonly used for the measurement of very high vacuum (or very low absolute pressure) but Bourdon elements can also be used for such applications.

BOURDON ELASTIC ELEMENTS

The Bourdon elastic element is one of the most widely used pressure-sensitive devices. Bourdon elements are sometimes called Bourdon tubes, Bourdon springs, or simply Bourdons. Bourdon elements are made in several shapes to suit various applications. However, all Bourdon elements operate on the same general principles.

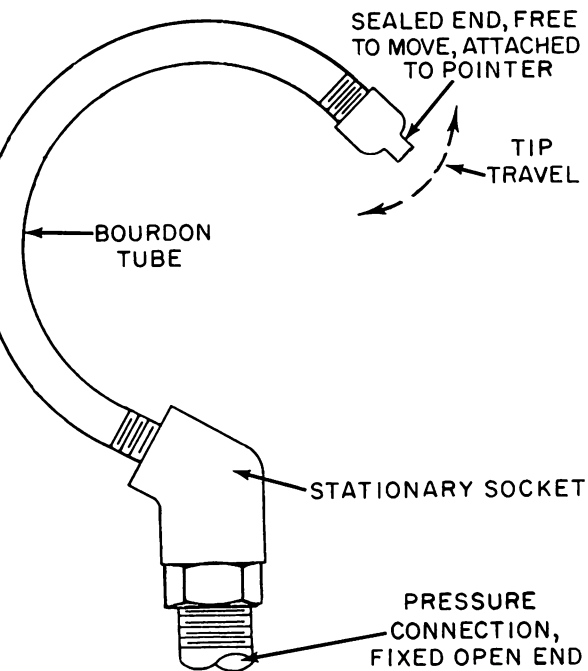
The Bourdon tube is a device that senses pressure and converts the pressure to displacement. Since the Bourdon tube displacement is a function of the pressure applied, it may be mechanically amplified and indicated by a pointer; thus, the pointer position indirectly indicates pressure.

The basic Bourdon structure most commonly used is a curved or C-shaped metal tube that is sealed at one end and open at the other. The other types of Bourdon tubes are the spiral and helical.) The C-shaped Bourdon tube shown in figure 5-5 is probably the most widely used Bourdon form. The open end of the tube is fixed in position; the sealed end is free to move. The tube is more or less elliptical in cross section. The cross section of a tube that is sealed at one end tends to become more circular when there is an increase in the volume or in the internal pressure of the contained fluid, and this tends to straighten the tube. Opposing this action, the elastic quality of the tube metal tends to coil the tube. Thus, the Bourdon tube acts as a spring and obeys Hooke's Law. Since the open end of the Bourdon tube is rigidly fastened, the sealed end moves as the volume or pressure



61.4X

Figure 5-4.—Manometers. (A) Both legs of U-tube visible. (B) One leg of U-tube visible.



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Figure 5-5.—C-shaped Bourdon tube.

inside the tube changes. When a pointer is attached to the sealed end of the tube through appropriate linkages, and when the assembly is placed over an appropriately calibrated dial, the result is a Bourdon-tube gage that may be used for measuring pressure or other variables, depending upon the design of the gage and the calibration of the scale.

The application of pressure to a C-shaped Bourdon tube causes only relatively small amount of tip travel or top movement. In the typical C-shaped Bourdon tube of approximately 70°, the tip often does not move more than a quarter of an inch altogether. The exact amount of tip travel depends upon the length of the tube, the cross-sectional shape of the tube, and other design factors, as well as upon the amount of pressure applied.

In theory, the path taken by the tip of the tube is an arc or curve. But because the tip travel is limited to a very small segment of this curve, tip travel is regarded as being essentially straight-line or linear for C-shaped Bourdon tubes.

Since the tip travel of a C-shaped Bourdon tube is so small, it is necessary in most applications to multiply this movement in order to

obtain a reasonable amount of pointer travel. A system of levers and gears is usually used for this purpose.

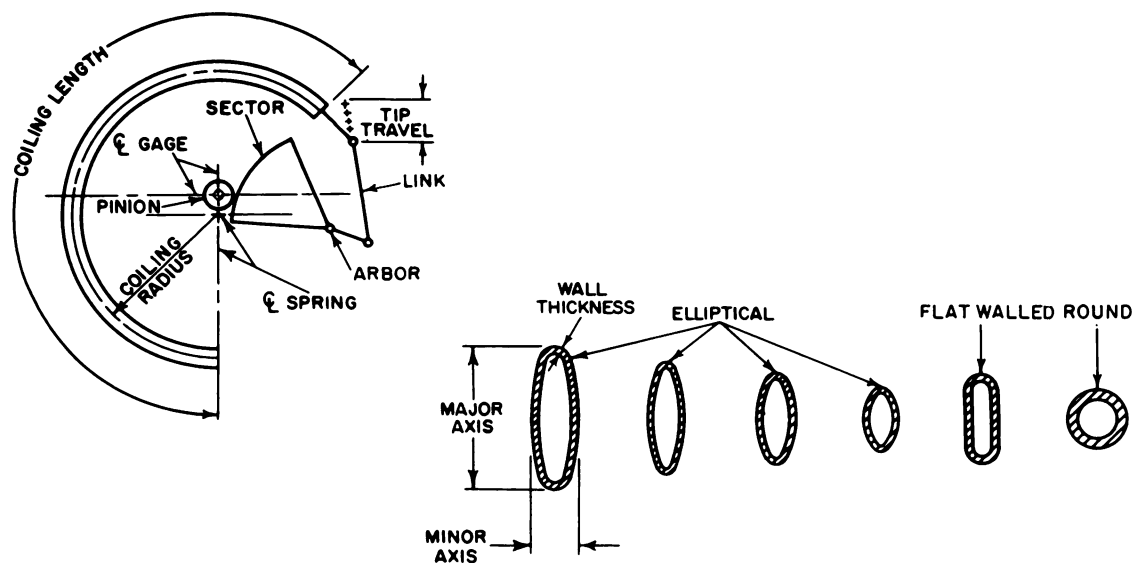
Figure 5-6 illustrates a gage designer's diagram with identification of the basic dimensions that must be considered to select the proper Bourdon spring. It should be noted that the cross-sectional shape of the Bourdon spring can be elliptical, flat walled, or in the case of extremely high pressures, approaching a perfect circle. However, the flat-walled type is most easily adapted to precise manufacture; therefore, it is used more frequently than other designs.

A flat spiral Bourdon element is shown in figure 5-7, and a helical Bourdon element is shown in figure 5-8. In each of these designs, the tube consists of several complete coils. Because these tubes are so long, the tip travel is also relatively long. In many applications, the tip travel of a spiral or a helical Bourdon tube is great enough to drive the pointer over the scale and even, in many applications, to drive a recording pen over a chart. Although gear trains are used in some gages that have spiral or helical Bourdon elements, many such gages are designed without gears.

Bourdon elements of all shapes and sizes are manufactured with great precision. They are made of brass, phosphor bronze, stainless steel, beryllium-copper, or other metals or alloys, depending upon the requirements of service.

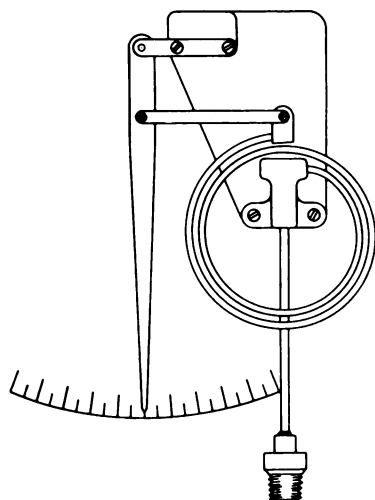
The mechanism by which the relatively short tip travel of a Bourdon tube is multiplied is called the **MOVEMENT** or the **GAGE MOVEMENT**. In many instances, the movement also performs the function of changing the direction of motion, since the pointer frequently moves in a different plane than the Bourdon tube. Many Bourdon-tube gage movements are of bronze; but special operating conditions may require the use of steel, Monel, or other special metals.

A movement for a simplex Bourdon-element pressure gage is shown in figure 5-9. The heart of this movement is the pair of mating gears. The complete full-circle pinion is part of the pointer shaft. The tooth sector, which is merely a segment of a much larger gear, is pivoted between the upper and lower movement plates. The upper and lower movement plates (also referred to as the frame) are spaced and held in position by posts. The movement plates vary considerably in shape. The part of the tooth sector that extends beyond the pivot



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Figure 5-6.—Bourdon spring "C" type and gage designer's diagrams.

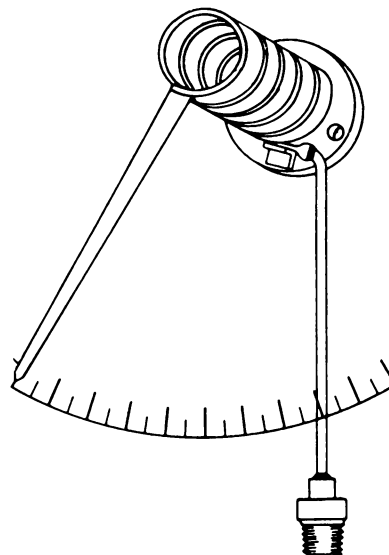


38.211(61C)DX

Figure 5-7.—Flat spiral Bourdon element.

point is called the sector slide. The end of the sector slide is fastened to a connecting link; the other end of this connecting link is fastened to the sealed, movable end of the Bourdon tube.

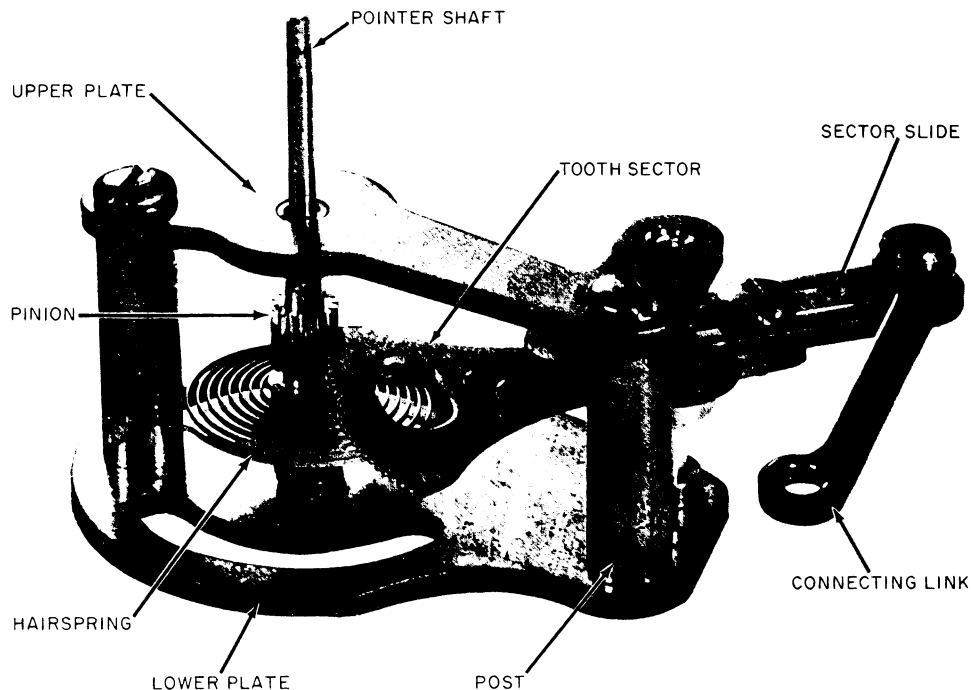
When pressure is admitted through the socket (open, stationary end of the Bourdon tube), the increase in pressure tends to straighten the



61.116X

Figure 5-8.—Helical Bourdon element.

tube, thus moving the free, sealed end. This moves the connecting link, which in turn pulls on the sector slide. The tooth sector, pivoting in its bushings, is thus moved in such a way that the teeth of the sector mesh with the leaves (formerly referred to teeth of the pinion gear)



38.211(61)C

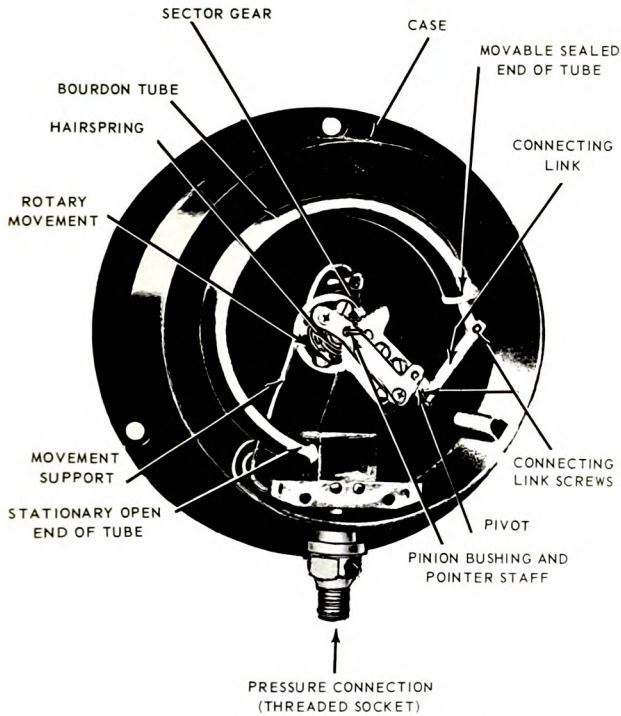
Figure 5-9. Movement for simplex Bourdon-tube pressure gage.

of the pinion. Since the pinion is part of the pointer shaft, the pointer is thus moved over a calibrated dial in response to the increased pressure.

The slotted sector slide provides for a range a adjustment. The connecting link is solid rather than adjustable in the movement shown; however, many gages have adjustable connecting links as well as adjustable sector slides. Some gages (including the one shown in figure 5-9) are so arranged that the entire movement can be rotated about the pointer shaft bushing, allowing for linearity adjustment. This type of movement is called a rotary movement. The actual procedures for adjusting various kinds of pressure gages are discussed in chapter 6 of this training manual. At this point, it is only necessary to take note of the fact that a good many different arrangements of movements and linkages are in common use. Indeed, you may open up a number of Bourdon-tube pressure gages without finding any two that are identical in all respects, even though they all operate on the same basic principles.

Some clearance is necessary between the leaves of the pinion and the sector teeth. To eliminate the pointer backlash that would otherwise occur upon reversal of pressure, a torsional hairspring is usually mounted on the pointer shaft (generally above the pinion). The other end of the hairspring is attached to one of the posts. The hairspring prevents backlash by continually applying a force that keeps the teeth properly engaged. The hairspring may be wound in either direction; in some gages the hairspring winds tighter as the pressure increases, while in other it unwinds as the pressure increases.

Figure 5-9 shows the movement and linkages without the Bourdon tube. In reality, however, the socket, the Bourdon tube, the linkages, and the movements form one assembly which may be removed as a unit from the case. Figure 5-10 shows the entire assembly inserted in the case, as it would appear from the front, with the dial and the pointer removed. Figure 5-11 shows the completely assembled gage. The pointer marked RED HAND is a manually positioned hand that is set to the normal working



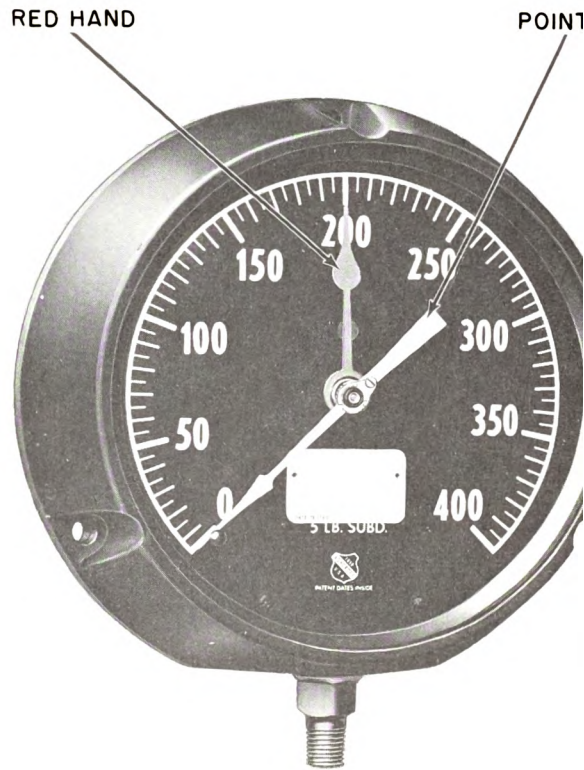
38.211(61)AX

Figure 5-10.—Socket, Bourdon tube, linkages, and movement installed in case. (Front view, with dial and pointer removed.)

pressure of the machinery or equipment on which the gage is installed; the hand marked **POINTER** is the only hand that moves in response to pressure changes.

Bourdon-tube gages are sometimes classified as being simplex or duplex, depending upon whether they measure one pressure or two. Now let's look at a duplex gage, as shown in figures 5-12, 5-13, and 5-14. As may be seen, a duplex gage has two Bourdon tubes, a double movement, linkages for each tube, and two pointers. Each mechanism acts separately, but the two pointers use a common dial. Thus a duplex gage gives simultaneous indication of the pressure at two different locations. A typical use of duplex gages is in the engine room to show that the lubricating strainers are open. When one element is connected to the strainer inlet and the other to the outlet, a clogged strainer will be indicated by a noticeable pressure difference.

Bourdon-tube vacuum gages are marked off in inches of mercury, as shown in figure 5-15. When a gage is designed to measure both vacuum



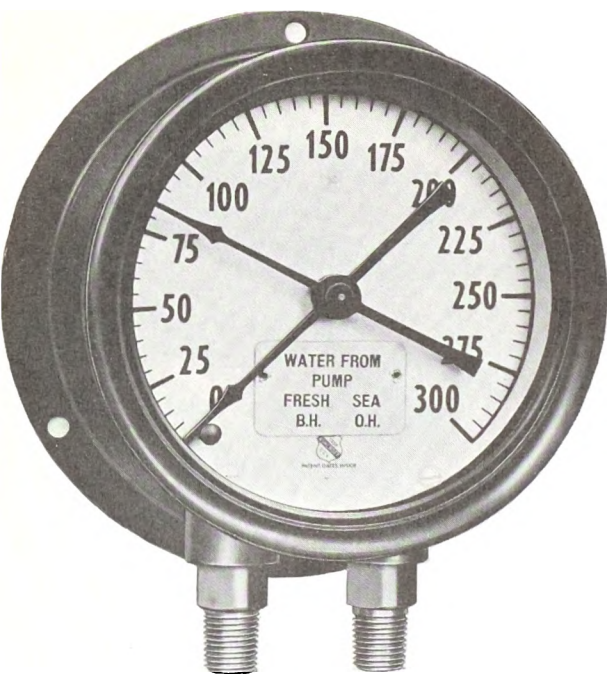
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Figure 5-11.—Assembled Bourdon-tube pressure gage.

and pressure, it is called a compound gage; it is marked off in both inches of mercury and psig, as shown in figure 5-16.

Differential pressure may also be measured with Bourdon-tube gages. One kind of Bourdon-tube differential pressure gage is shown in figures 5-17 and 5-18. This gage has two Bourdon tubes, each of which is linked to the gage movement in the manner shown in figure 5-18. Because of the way in which the tubes are connected to the movement, the single pointer of this gage always reflects the pressure **DIFFERENCE** between the high pressure input and the low pressure input.

The location of the zero point on a Bourdon-tube differential pressure gage varies, depending upon the type of service for which the gage is to be used. If the pressure from one source is **ALWAYS** be greater than the pressure from the other source, the zero point is located at low left in the customary position. If the pressure from either source may be greater, the gage

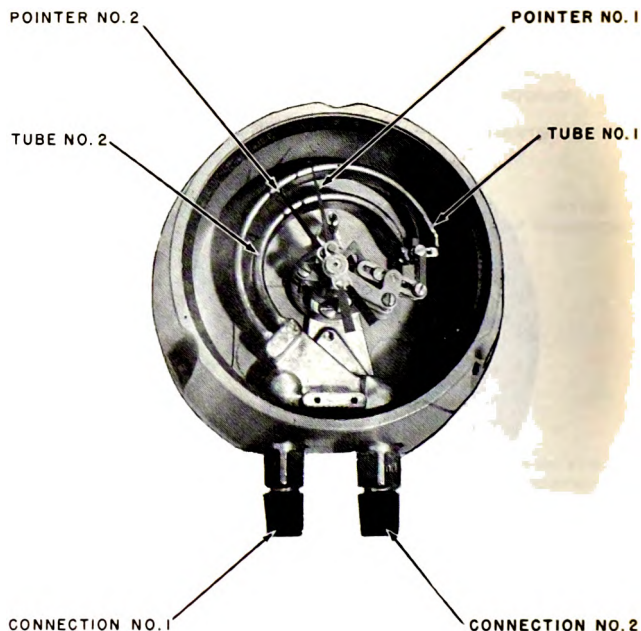


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Figure 5-12.—Assembled duplex Bourdon-tube pressure gage.

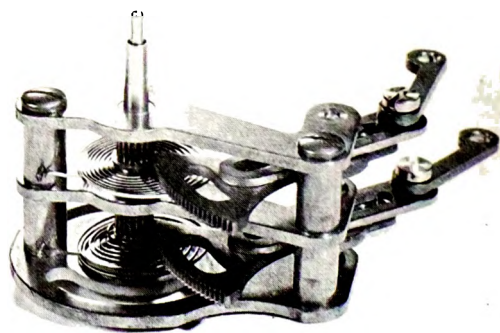
be designed to have the zero point at the top of the dial so that the pointer can move either to right or to left.

Bourdon-tube pressure gages are used in many hydraulic systems, and in this application they are usually referred to as hydraulic gages. Bourdon-tube hydraulic gages are not particularly different in basic operating principles from other types of Bourdon-tube gages; however, they do sometimes have special design features because of the extremely high pressures to which they may be exposed. For example, some hydraulic gages have a special type of spring loaded linkage that is capable of taking overpressure and underpressure without damage to movement and keeps the pointer from slamming back to zero when the pressure is suddenly changed. If a hydraulic gage does not have such a device, it must be protected by a suitable check valve. Hydraulic gages may also have special dials that indicate both the pressure (in psi) and the corresponding total force being applied. Another more or less special feature found in some hydraulic gages is a maximum



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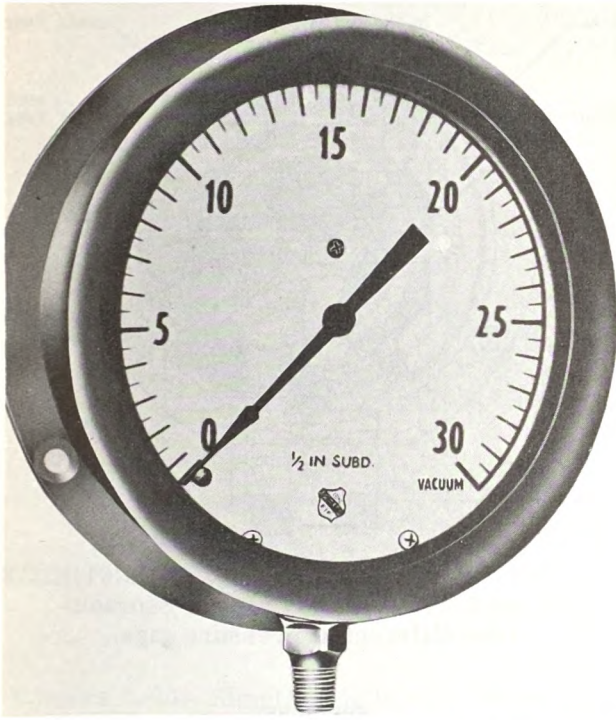
Figure 5-13.—Bourdon tubes and movements inserted in case of duplex pressure gage.



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Figure 5-14.—Movement for duplex Bourdon-tube pressure gage.

indicating pointer that indicates the highest pressure reached during a particular period. The maximum indicating pointer is not attached to the gage movement; instead, it is moved



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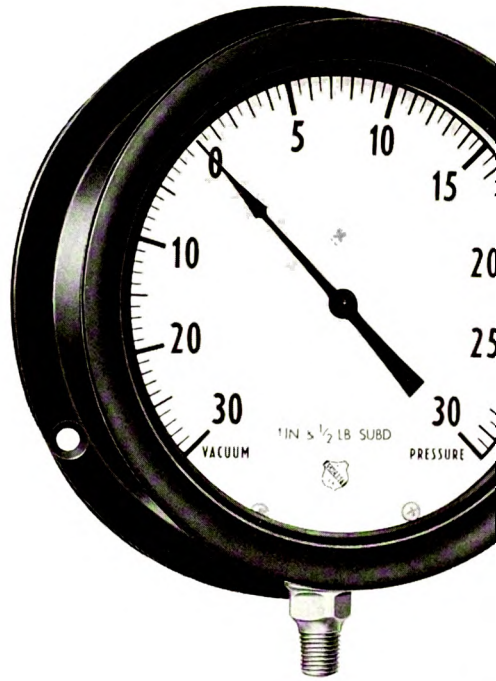
Figure 5-15.—Bourdon-tube vacuum gage.

upward by the regular pointer. When the regular pointer returns to zero (or to some point below the highest point it has reached) the maximum indicating pointer remains at the highest position it has reached. (Note: The Navy uses hydraulic gages to indicate pressures on hydraulic rams such as those on ships' steering gear and anchor windlasses. The dial indicates both the pressure in psi and the corresponding tons of load on the ram.)

The Bourdon-tube gages we have considered here are a mere sampling of the gages you may come across in your work with instruments. However, a thorough understanding of even these few gages should give you a basis for understanding other types of Bourdon-tube gages you may encounter.

BELLOWS ELASTIC ELEMENTS

A bellows elastic element is a one-piece convoluted unit that expands and contracts axially with changes in pressure. The radial expansion of a bellows is so very slight that it need not be considered. The pressure to be measured can



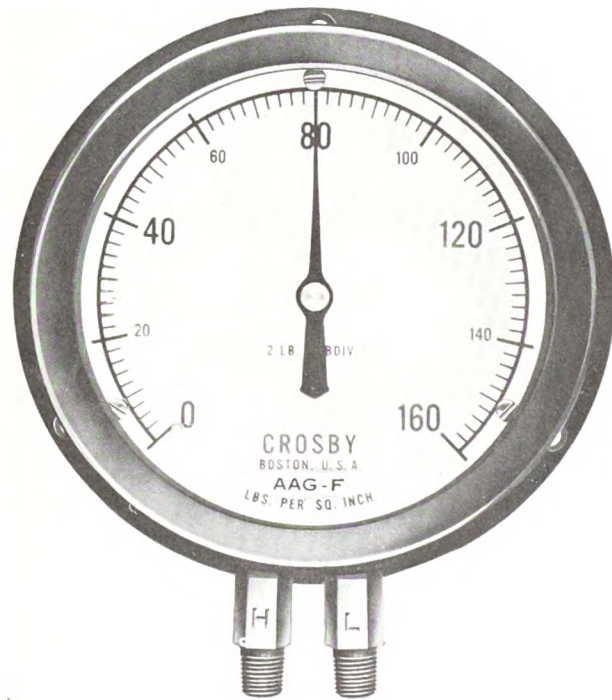
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Figure 5-16.—Bourdon-tube compound gage.

be applied to the outside of the bellows, as shown in figure 5-19, or to the inside of the bellows, as shown in figure 5-20. The elastic elements are made of brass, bronze, stainless steel, beryllium-copper, or other metals suitable for the intended use of the gage. A bellows is usually formed by making deep folds or corrugations in thin metal tubing or welding individual coils of metal at the peaks of the corrugations to form a continuous series of convolutions. The required number of convolutions depends on the required range of pressure.

Most bellows-type gages are spring-loaded, that is, a spring opposes the bellows action and prevents full expansion. Limiting the expansion of the bellows in this way protects the bellows and prolongs its life. In a spring-loaded gage, both the bellows and the spring act as elastic elements in the true sense of the word. The combination of the bellows and the spring is the sensing element. Because of this combination, the relationship between applied pressure and bellows expansion is linear.

Some bellows-type gages have gear trains that are quite similar to the gear trains used in Bourdon-tube gages. A gear train for a bellows-type gage is illustrated in figure 5-17.



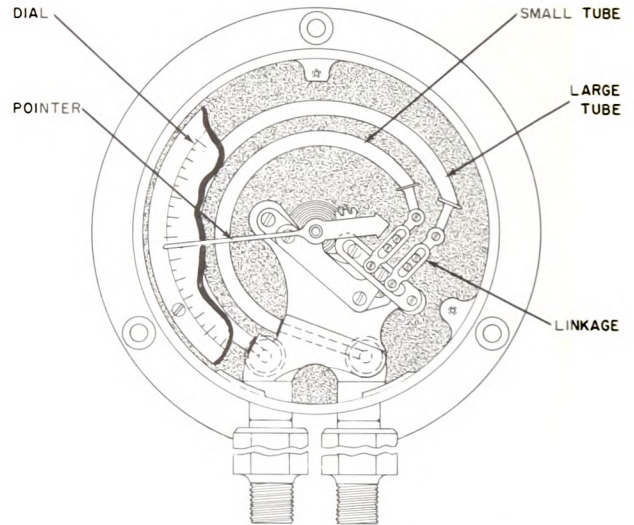
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Figure 5-17.—Bourdon-tube differential pressure gage.

figures 5-21 and 5-22. However, it should be noted that a bellows-type gage does not always require a geared movement, since a bellows has considerably greater movement than a Bourdon tube. Bellows elements are used in many applications where the pressure-sensitive device must be powerful enough to operate not only the indicating pointer but also some type of recording device.

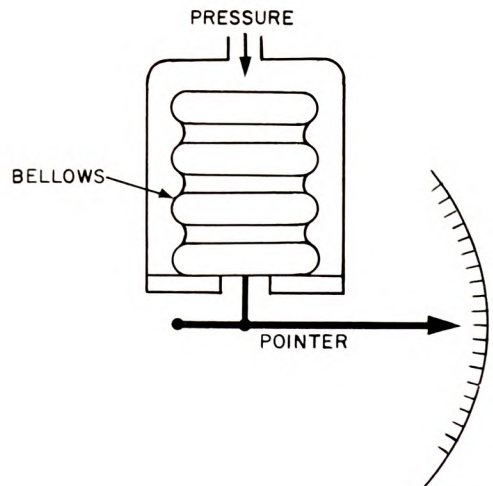
The amount of axial movement of a bellows element depends upon the number of convolutions in the bellows. The greater the number of convolutions, the longer will be the axial movement (or stroke, as it is called). The amount of force developed on each stroke depends upon the diameter of the bellows, with the greater force being developed by bellows of larger diameter. By the use of fairly large diameters, therefore, it is possible to measure very low pressures and still have enough force to position the pointer and, in some instances, a recording device.

Although some bellows-type measuring devices have been designed to measure pressures up to 800 psig, the primary application of



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Figure 5-18.—Cutaway view of Bourdon-tube differential pressure gage.

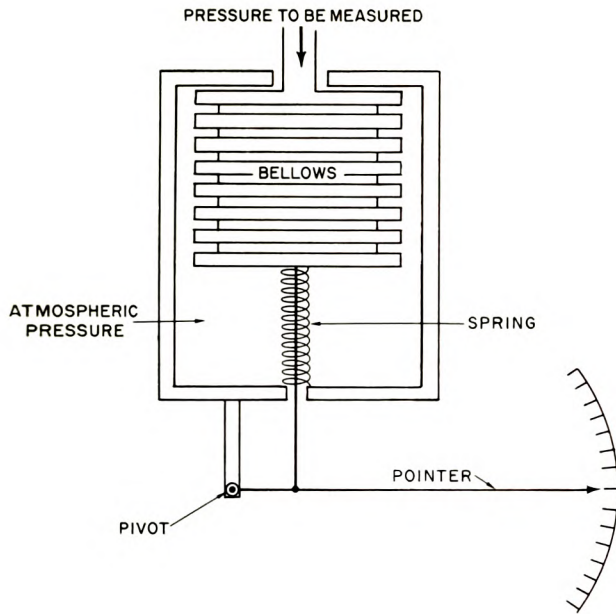


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Figure 5-19.—Simple bellows-type gage (pressure applied to outside of bellows).

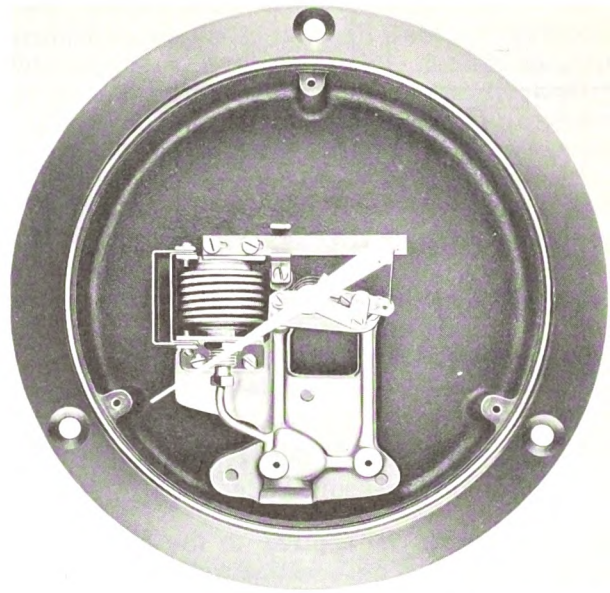
bellows elements is for the measurement of quite low pressures or small pressure differentials. For example, bellows elements are widely used in boiler control systems and in other pneumatic control systems that operate with low pneumatic pressures.

Many differential pressure gages are of the bellows type. In some designs, one pressure is applied to the inside of the bellows and the



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Figure 5-20.—Simple bellows-type gage (pressure applied to inside of bellows).



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Figure 5-21.—Bellows-type gage (front view, with dial removed).

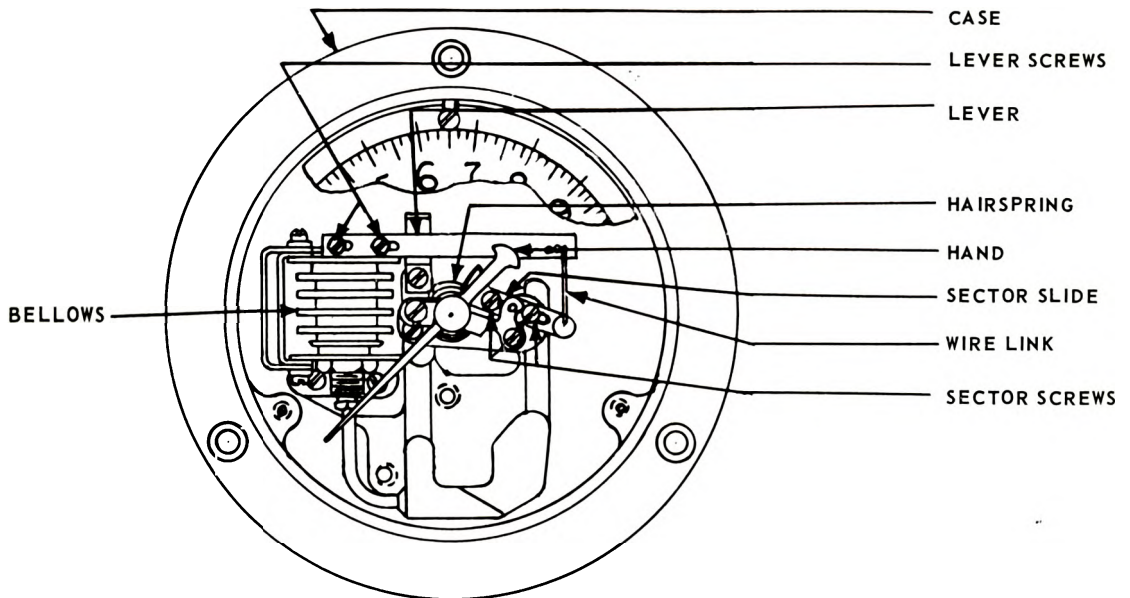
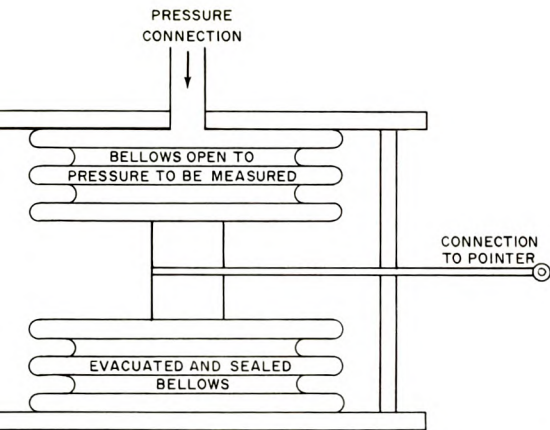


Figure 5-22.—Diagrammatic view of bellows-type gage.

61.3C2



61.3(61C)B

Figure 5-23.—Bellows-type absolute pressure gage.

pressure is applied to the outside. In other designs, a differential pressure reading is obtained by opposing two bellows in a single unit. A differential bellows gage may have one bellows that is evacuated and sealed, while the pressure to be measured is admitted to the

other bellows; this design results in a gage that measures absolute pressure. A bellows-type absolute pressure gage is shown in figure 5-23. (NOTE: Evacuated bellows act like an aneroid barometer to detect changes in atmospheric pressure and compensate for them by acting on the lever.) Figure 5-24 illustrates a bellows unit assembly in The Barton Model 200 pressure gage.

DIAPHRAGM ELASTIC ELEMENTS

Diaphragm elastic elements are used for the measurement of relatively low pressures or small pressure differentials. Both metallic and nonmetallic diaphragms are in use. Typical applications for diaphragm gages include: low pressure absolute pressure gages, draft gages, pneumatic receiver gages, liquid level gages, and differential pressure gages.

Metallic diaphragm elements are made from stainless steel, phosphor bronze, brass, or other metals suitable for the intended service of the gage. Each metallic diaphragm element consists of one or more capsules. Each capsule consists of two diaphragm shells which are welded, brazed, or otherwise firmly fastened

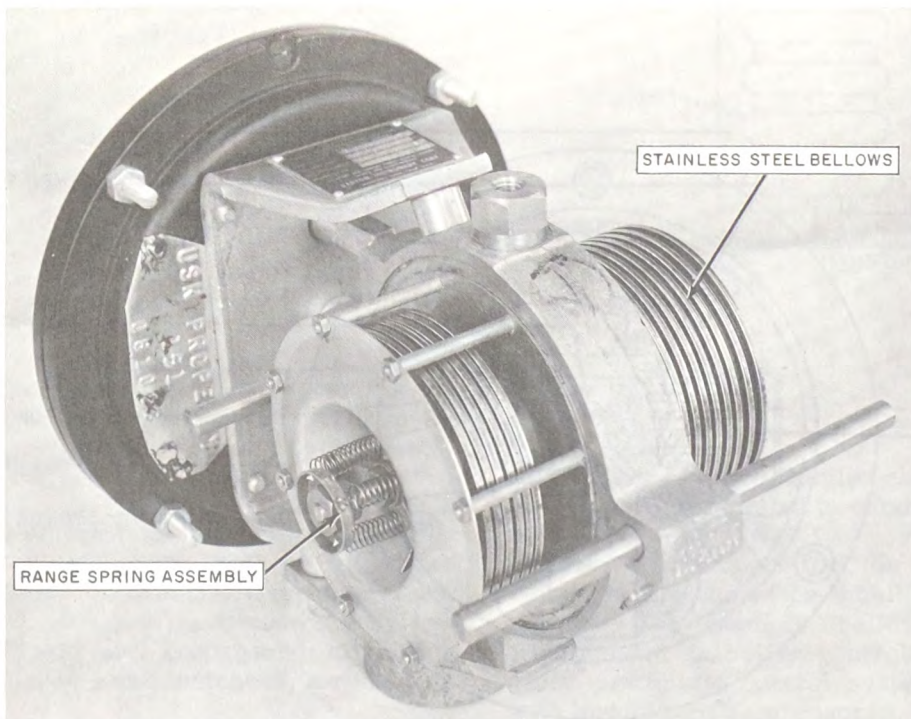


Figure 5-24.—Bellows unit assembly in the Barton Model 200 pressure gage.

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together. The diaphragm shells may have flat surfaces or corrugated surfaces. The capsules are all rigidly connected so that the application of pressure causes all capsules to collapse or deflect. The amount of deflection of a diaphragm-type element depends upon the number of capsules, the diameter of the capsules, the design and number of corrugations, and other design factors.

The important difference between the diaphragm and bellows elements is this: a bellows element consists of one continuous convoluted unit, while, a diaphragm element consists of one or more separate capsules, each of which is individually sealed.

The individual capsules of a metallic diaphragm gage may be evacuated so that the gage will measure absolute pressure. A schematic of a metallic diaphragm gage is illustrated in figure 5-25.

Nonmetallic diaphragms, also called slack or limp diaphragms, are made of leather, treated cloth, neoprene, or some other soft material. Although these materials are not elastic in the

true sense of the term, the gages that use slack diaphragms are considered as elastic element gages. Why is this? Because the diaphragms are opposed by calibrated springs or other devices that are truly elastic.

One type of nonmetallic diaphragm pressure gage is shown in figure 5-26. When pressure is applied to the underside of the slack diaphragm, the diaphragm moves upward. The upward movement of the diaphragm is opposed by the action of the calibrating spring. As the spring moves, the linkage system causes the pointer to move to a higher reading.

Some metallic diaphragm gages have a geared movement that is similar to the geared movements we have previously considered. Other metallic diaphragm gages, and practically all slack diaphragm gages, do not require the geared type of movement.

COMBINATIONS OF ELASTIC ELEMENTS

The three basic types of elastic elements we have considered here are widely used

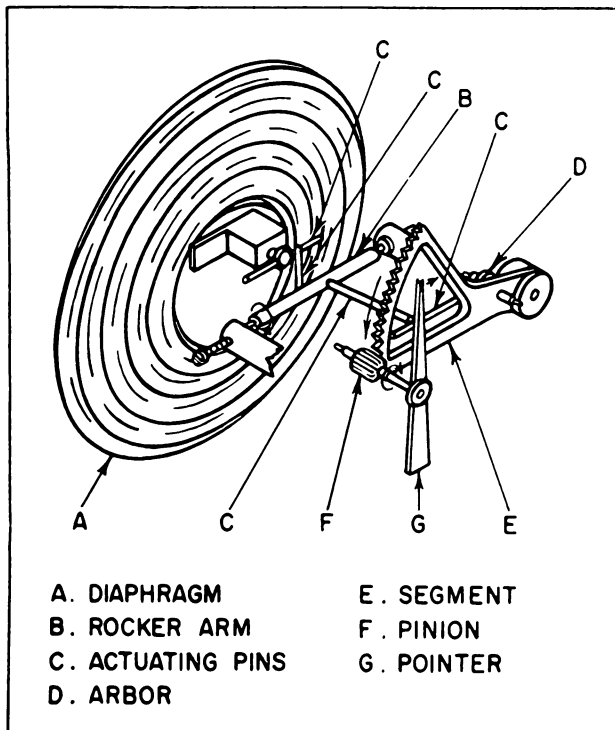


Figure 5-25.—Schematic of a metallic diaphragm gage.

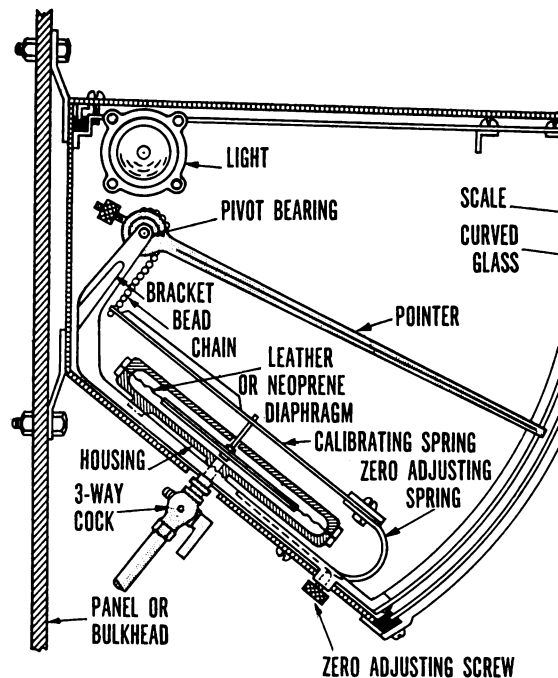


Figure 5-26.—Nonmetallic diaphragm pressure gage.

gages designed to measure gage pressure, absolute pressure, vacuum, and pressure differentials. They are also used in devices designed to measure temperature, fluid flow, liquid level, and other variables where the value of the variable is directly related to or may be inferred from the measurement of pressure or pressure differentials.

Although most pressure gages utilize only one type of elastic element, there is no law that says you can't use different types of elastic elements in the same instrument. In fact, you will often find a Bourdon tube used in the same gage with one or more bellows or diaphragm capsules, or bellows elastic elements used with diaphragm capsules. Such combinations of elastic elements are particularly common in boiler control systems and other pneumatic control systems. Combinations of elastic elements are very useful where one instrument is designed to receive one or more pneumatic pressures (signals) from one or more sources, to alter and/or combine the signal or signals it receives, and then to send the resulting new pneumatic pressure signal to another pneumatic unit in the control system.

ACCESSORIES AND SPECIAL EQUIPMENT

Thus far in this chapter we have been chiefly concerned with pressure-sensitive devices and with the movements and linkages by which the motion of a pressure-sensitive device is amplified and transmitted to an indicating pointer. However, the pressure-sensitive element and the movement and linkages cannot really function as a pressure gage until they are installed in a case and fitted with certain accessories and any necessary special equipment. So let's take a look at some of the items that may be considered as gage accessories or as special equipment required for certain types of service.

CASES

Pressure gage cases are designed to keep the gage movement clean and free of dust, moisture, and other contaminants. Gage cases are made of various metals, including brass, cast iron, and steel. Some gages have phenolic plastic cases. Special safety features are incorporated in the cases used for oxygen gages, high pressure gages, and other gages that are used for hazardous service.

Safety gage cases are made with a partition dividing the dial from the Bourdon tube and movement. The gage back or a portion of it is a blowout disk for relieving the pressure in the event of a rupture of the Bourdon tube. A chain is supplied to limit the flight of the disk.

It should be noted that safety cases are also used in steam (all superheated steam), and refrigerants, oils, water, and other liquid applications at pressures above 1000 psi.

The design of gage cases depends partly upon the preference of the manufacturer, partly upon the size and style of the pressure element, and partly upon the intended service of the gage. In general, round cases are used for gages that have C-shaped Bourdon tubes. The cases for other types of pressure gages may vary considerably.

Some pressure gage cases are designed for surface mounting; others are designed for flush mounting on a gage board. The main difference between the two types is in the location of the socket and pressure connection. For a flush-mounted gage, the connection is normally made through the back of the case; for a surface-mounted gage, the connection is made through the side of the case, usually at the bottom.

Pressure gage cases are classified as being either solid-back cases or solid-front cases. In a solid-back case, the back of the case is integral with the side. In a solid-front case, the front of the case is designed so that excessive pressures cannot cause the front to blow out. Instead, the back of a solid-front case is specifically designed to blow out at a relatively low pressure. Most Bourdon-tube gages have cases of the solid-back type. Solid-front gages are used for reasons of safety in certain applications; since the front cannot blow out, the back must blow in the event that excessive pressure builds up. The part of the back that is designed to blow out is usually fastened to the gage case with a strong stainless steel chain so that the blowout piece will not go flying around if it does blow out.

Figure 5-27 illustrates several common designs of Bourdon-tube pressure gage cases. As may be seen, the cases may be flanged at the back, flanged at the front, or not flanged at all.

In a solid-back gage, the gage assembly is fitted into the case and then secured in place by screws inserted through holes in the back of the case. The dial is then positioned over the movement, with the hole in the center of the dial

fitting over the pointer staff. The pointer is then set in place. Finally, the glass face and the ring are installed. There is considerable variation in bezel design.

The bezel, sometimes referred to as a ring, secures the lens to the case. In most gage designs, it must be removed to gain access to calibration adjustments, or to remove the internal parts for maintenance and replacement. The ease with which the bezel can be removed depends upon whether the gage is an inexpensive "throw-away" which can be replaced almost as cheaply as it can be maintained, or a quality precision instrument that must be checked and calibrated frequently for top performance. Cross-sections of common types of bezels are shown in figure 5-28. The bezel is fastened to the case by

means of (1) a friction or press fit, (2) a slip fit with retaining screws, and (3) a threaded fit.

Additional information concerning bezels can be obtained from manufacturer's technical publications for specific equipment.

DIALS

Pressure gage dials vary widely with respect to the range of pressures indicated on the scale. Most scales start at zero and go to some point that is above the highest normal working pressure. However, some gages have suppressed-zero scales. A scale of this type might start, say, at 50 psi and go to 100 psi, rather than starting at zero and going on up to 100 psi. Figure 5-29 shows a suppressed scale gage. The reason for using a suppressed-zero scale (generally suppressed to 50 psi) in certain applications is to provide larger scale increments over the actual working range of the

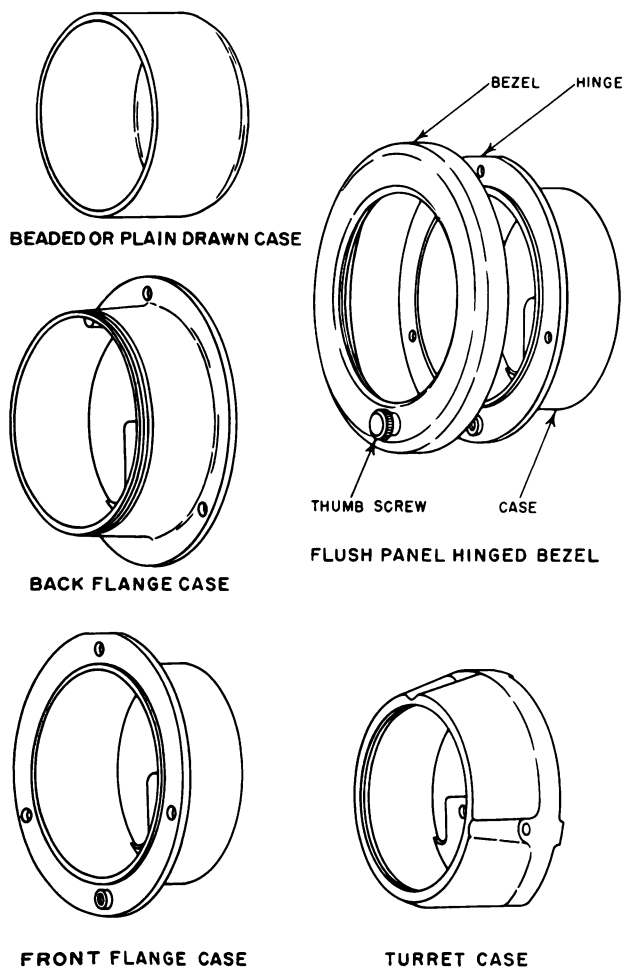


Figure 5-27.—Common case designs for Bourdon-tube pressure gages.

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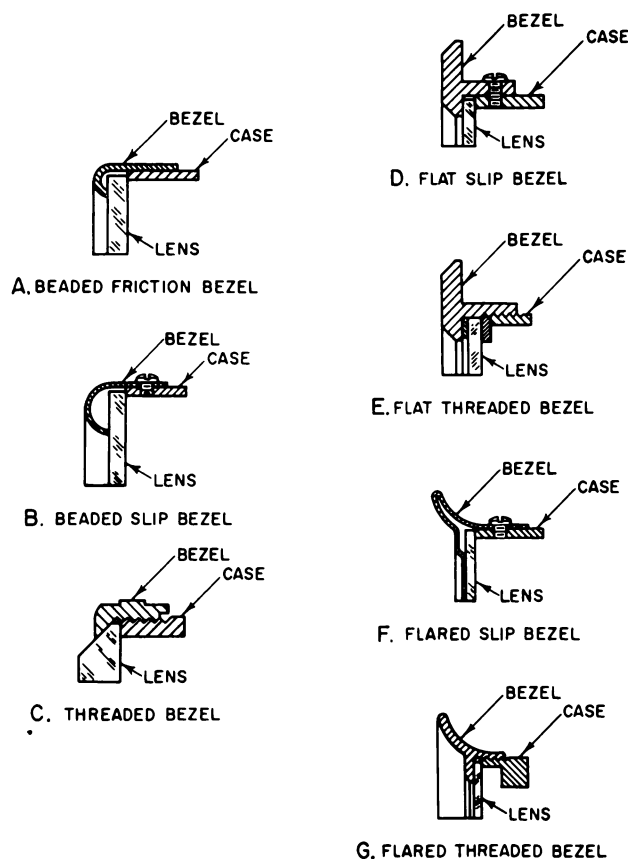
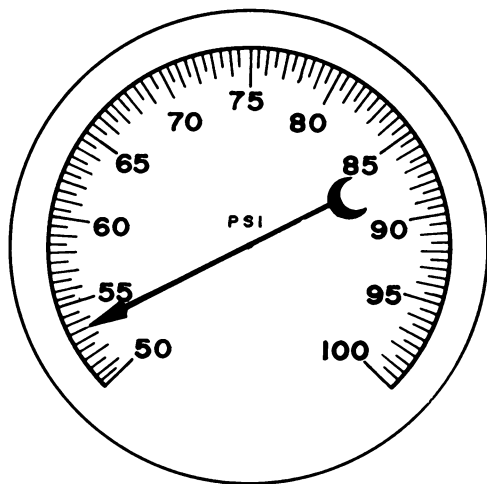


Figure 5-28.—Cross sections of common types of bezels.

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Figure 5-29.—Suppressed scale gage.

scale than would be possible with a regular scale of the same size. (NOTE: Suppression is accomplished by means of a slotted linkage and stop arrangement.)

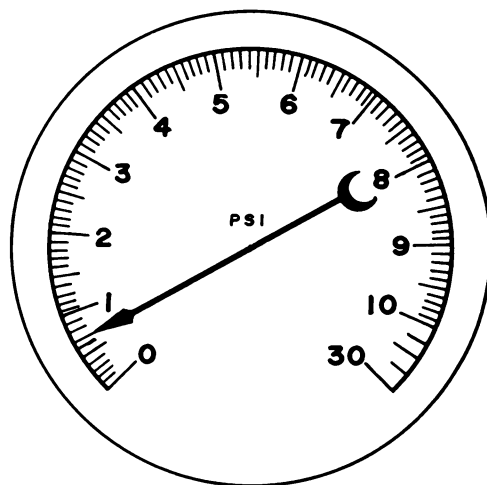
Retarded scale gages, however, have scales in which either one or both ends is/are compressed. The dials of these gages, retarded from 10 to 30 psi, have scales that start at some point above zero. The free motion of the Bourdon element is modified by engagement with a spring in the retard zone. Figure 5-30 shows a retard scale gage.

In the case of a retard gage, the accuracy is expressed as a percentage of the expanded portion of the scale. The grade of the gage is not affected by the accuracy of the compressed portion of the scale.

Pressure gage dials are usually either white with black markings or black with white markings. Dials are usually made of thin metal or plastic. They are usually designed to be non-reflecting. Some dials are illuminated by internal lighting.

POINTERS

There are several kinds of pointers in use. The most common type is a simple balanced pointer which must be removed from the pointer staff and then reset in order to change the pressure setting. Another type of pointer is the micrometer or adjustable pointer; this type can



61.121

Figure 5-30.—Retarded scale gage.

be reset merely by turning an adjusting screw to the right or to the left, without removing the pointer from the pointer staff. Some gages also have manually positioned pointers to indicate the normal working pressure or some other significant pressure. These manually positioned pointers do not, of course, move with pressure changes. Still other pointers are designed to indicate the maximum pressure reached during any particular period; these maximum pressure pointers are described in the previous discussion of hydraulic gages. Some pointers have electrical contacts for activating an alarm system or for transmitting an electrical signal in a control system.

OVERRANGE AND UNDERRANGE STOPS

Mechanical stops are frequently used in pressure gages to prevent damage to the gage in the event of too much or too little pressure. These stops, which are often referred to as overrange and underrange protective devices, are usually in the form of bars or posts which limit movement travel so that the sector and pinion do not disengage as a result of over or under pressure.

SEALING DEVICES

In considering Bourdon-tube pressure gages, we have more or less taken for granted that the pressure is measured by allowing the fluid to

enter the Bourdon tube. This is not always the case, however, so we must now consider some of the accessories that are used when it is necessary to keep the measured fluid out of the Bourdon tube.

One way to keep the measured fluid from entering the elastic element is to use a filled system consisting of a diaphragm at the pipe or tubing to the sensor pressure connection, and filled with a liquid such as glycerine or a silicone liquid. This type of filled-system gage is widely used for measuring pressures in chemical fluids which would corrode the Bourdon tube if they made direct contact with it; because of this common usage, filled-system pressure gages are often called chemical gages.

The diaphragm in a chemical gage is held in place by a flanged connection; this whole unit is sometimes called a gage protector. The diaphragm keeps the measured fluid from entering the socket or the Bourdon tube. Instead, the pressure of the measured fluid is applied to the underside of the diaphragm and thus transmitted to the filling liquid. Since the filling liquid is incompressible, for all practical purposes, the pressure of the measured fluid is transmitted to the Bourdon tube. The free end of the Bourdon tube moves in response to pressure changes, just as in any other type of Bourdon-tube gage.

Since the diaphragm is relatively small and is held rigidly in place by the flanged protector, any large displacement of the diaphragm would cause the diaphragm to rupture, thus ruining the gage. For this reason it is essential that the system be **SOLIDLY** filled with liquid, without any pockets of air or other compressible gas. If it is not solidly filled, the pressure applied to the underside of the diaphragm would cause the diaphragm to be displaced, possibly to the breaking point of the diaphragm.

In order to prevent the accumulation of air or other gases in the filled part of the system, some Bourdon tubes for chemical gages are made with a bleed or vent opening at the tip of the Bourdon tube. This opening makes it possible to completely and solidly fill the tube with the filling liquid. Chemical gages are always calibrated after the system has been filled and sealed.

Another fluid that must not be allowed to enter a Bourdon tube is steam. Although steam does not corrode the Bourdon tube, as many chemicals would, the heat of the steam would be damaging to the tube. The solution to the

steam gage problem is much simpler than the solution to the chemical gage problem. Steam gages are always installed with a coil of exposed, uninsulated tubing in the line leading to the gage. This coil, which is called a syphon or a pigtail, provides a place in which the steam can condense into water, thus providing a constant seal of condensate between the gage and the gage line. The syphon or pigtail is filled with water before the gage is installed, so that steam does not ever enter the pressure element. Syphons or pigtails may also be used on other types of pressure gages, as well as on Bourdon tube gages; for example, the manometer shown in part B of figure 5-4 shows a syphon in the line leading to the gage.

PRESSURE CONNECTIONS

Gage connections may be either at the back or at the bottom of the case with either threaded or welded nipples. Threaded nipples are American Standard 1/4 inch IPS for ranges up to and including 0 to 5000 psi and 1/2 inch IPS for ranges above 5000 psi. Welding nipples are 1/2 inch IPS, approximately 4 inches long. Oxygen service gages are always furnished with welding nipples.

Gages having a range of 0 to 5000 psi or greater are provided at the connection with a throttle screw as a means for limiting the flow in the event of Bourdon tube failure.

Additional information on pressure gage connections, with respect to installation of gages, is covered later in the chapter.

PULSATION DAMPENERS

Rapid pulsations of flow in the fluid being measured would be severely damaging to the pressure elements and to the geared movement of pressure gages. A number of gage accessories have been developed to cope with this problem. In general, these devices are designed to restrict the flow of fluid by some type of obstruction in the line. Restricting the flow of fluid tends to smooth out the pulsations and thus to give an average reading on the scale rather than a reading that reflects every rise and fall of pressure.

The simplest pulsation dampening device is a needle valve installed in the line leading to the pressure gage. Screens or filters are also used as pulsation dampeners; these may be made of porous metal, felt, or other materials that

restrict the flow of fluid enough to smooth out the pulsations and require periodic cleaning or replacement. Still another type of pulsation dampener consists of a piston that moves up and down inside a tube in response to pulsations; this type of dampener, which is often called a snubber, is used where a gage would otherwise be subjected to sudden shock pressures as well as to pulsation.

Dampeners must be removed prior to cleaning and/or calibration of the gage. The dampeners used by the Navy are connected in the line ahead of the gage. They have 1/4 inch IPS American Standard threads, male on one end and female on the other end.

Four types of dampeners are available for the following services:

- Type I—Oil service above a viscosity of 225 Saybolt Seconds Universal (SSU) at operating temperature.
- Type II—Gasoline, fresh water, light oil (below 225SSU) or steam.
- Type III—Gases.
- Type IV—Sea water.

These dampeners are made in three working pressure ranges: 0 to 800 psi, 801 to 5000 psi, and 5001 to 15,000 psi.

CLEANING OF GAGES

Periodic gage cleaning should be accomplished with a recommended cleaning solution either in an ultrasonic cleaner or by hand. Even when an ultrasonic cleaner is used, bushings should still be cleaned with a piece of sharpened pegwood and pivots should be cleaned with a piece of pithwood and polished with a crocus cloth if necessary. Before reassembling a gage, see that all parts are dried and the bushings and pivots clear of gummy residue. If the parts are dried with a low pressure air jet, do not use air pressure around the hair-spring.

When handling cleaned parts, hold them by their edges or with a pair of tweezers to avoid spoiling the finish; body acid etches parts.

Additional information dealing with cleaning procedures for gages is covered in chapter 6 of this training manual.

PRESSURE GAGE INSTALLATION

Although some pressure gages may be mounted directly on the machinery, pressure

vessel, or piping system in which the pressure is to be measured, it is far more common to find the gages mounted on a bulkhead or on a flat-faced gage board. In every situation, it is extremely important to mount gages in such a way as to minimize vibration. A precision gage can be ruined in a very short time if it is not protected from vibration. The problem is particularly urgent with gages used aboard ship, since some ships experience very great structural vibration from screws and machinery. When gage boards are mounted on the same base as the rotating machinery, the instrument is designed to minimize the effects of vibration, and springs or resilient mounts are used to isolate the instrument from the vibration. Resilient rubber washers are used on the securing bolts between the gage case and the gage board. If the gage instrument piping is subject to vibration, a flexible connector or loop is used between the vibrating line and the gage board.

Pressure gage connections must always be supported so that no stress will be transmitted to the gage mechanism, or indicator. This is one reason why pressure gage mechanisms are designed to be independent of the cases.

Precautions must be taken to avoid leaking joints in gage connections. If there is a leak in a steam pressure gage connection, the condensate seal may be lost; this is likely to result in damage to the gage and in false readings. Vacuum gage connections require particular attention, since it is not always easy to notice leakage at a vacuum connection.

Most pressure gages are installed with a gage cock and test connection in the line near the gage. The gage cock is a small valve that allows the gage to be isolated and removed for testing or replacement without having to shut down the whole system. The test connection is used when checking the indicator with a portable tester.

The total length of a gage line and the inside diameter of the line have a definite effect on the speed of response of a pressure gage. Designed specifications must always be followed with respect to the total length of the line and the inside diameter of the line. This is particularly important in certain applications where rapid response is important—as, for example, in various control systems. Too long a line or too large a line could really upset the functioning of a control system that depends upon receiving a pressure signal within a certain time limit.

When possible, pressure gages should be installed in such a way that they will be easily accessible for removal, adjustment, or repair. Aboard naval ships, where a good deal of equipment must be crammed into small spaces, this is sometimes easier said than done. However, every effort should be made to locate pressure gages in accessible positions.

Pressure gage connections are normally made at the top of the line or unit in which the pressure is to be measured. Occasionally, however, it is necessary to locate a pressure gage some distance below or above the line or the unit. If the fluid being measured is a liquid (or if it is a gas that readily condenses into a liquid) the location of the gage with respect to the line (piping) or the unit affects the readings

on the gage. If the gage is located below the line, the uncorrected gage reading shows MORE pressure than actually exists in the line; if the gage is located above the line, the uncorrected gage reading shows LESS pressure than actually exists in the line. (This is particularly important on differential pressures.) The required corrections should be adjusted in the calibration of pressure gages, if possible; if they are not made during calibration, they must be calculated by each person reading a gage that is installed above or below the pressure source.

The user of a gage should be notified by the calibration activity as to what corrective action should be taken. Additional information on calibration of gages is covered in chapter 6 of this training manual.

CHAPTER 6

PRESSURE GAGE MAINTENANCE AND REPAIR

Pressure gages require testing at specified intervals, in accordance with manufacturer's recommendations. Also, they may become worn, dirty, or damaged, and they may get out of adjustment in various ways. This chapter deals with procedures for testing, inspecting, repairing, cleaning, adjusting, and calibrating pressure gages. Chapter 14 of this training manual takes up certain repair and manufacturing processes that may be required in connection with the repair of pressure gages and other measuring devices.

BASIC GUIDELINES

Before taking up the equipment and procedures used for the maintenance and repair of various kinds of pressure measuring devices, let's look at some basic principles and precautions that apply to pressure gage work. A few important guidelines are noted in the following paragraphs.

HANDLE GAGES CAREFULLY.—Most of the pressure gages you will be working on are delicate and expensive precision instruments. Even a "rugged" gage is a comparatively delicate instrument and should be handled with care.

USE PROPER TOOLS.—Before starting to work on pressure gages, assemble all the tools and equipment you will need. In addition to the major items of equipment such as pressure gage testers and cleaning machines, you will need a number of small items. These small items may include several sizes of standard screwdrivers, clock screwdrivers, and perhaps Phillips or fillister screwdrivers; screw starters; pointer removers (also called pointer pullers); pointer installing tools (also called pointer sets); needle-nose pliers; tweezers;

light mallets; dishes or other containers for small parts; pithwood; orangewood sticks; polishing cloth; stiff-bristled brushes; clean rags; and cleaning and rinsing solutions.

It is important to use the correct tool for each operation. Always use the correct size and type of screwdriver; screws, threads, and screwdrivers can be ruined otherwise. Do NOT use any tool for purposes to which it is not adapted. Just because you have a screwdriver in your hand is no reason to use it when some other tool would be more appropriate.

FOLLOW MANUFACTURERS' INSTRUCTIONS.—Pressure gages vary in design and construction, so the procedures for disassembling, repairing, reassembling, and calibrating gages may also vary. The best guidelines for the maintenance and repair of a specific type of pressure gage are usually the instructions furnished by the manufacturer. If such instructions are not available, you will have to proceed on the basis of common sense and previous experience with similar gages. But don't overlook the fact that manufacturers' instructions are worth hunting for; they can save you a lot of time and prevent a lot of mistakes. It is important to follow the manufacturers' instructions for using specific items of pressure gage test equipment, discussed later in the chapter.

OBSERVE 3-M SYSTEM REQUIREMENTS.—The adoption of the 3-M System has led to increasing standardization of the requirements and procedures for maintenance and repair. As an Instrumentman, you should be aware of the 3-M System requirements concerning your own shop equipment. Also, when working on equipment for other ships, you must be aware of the importance of completing all forms promptly and accurately.

It should be noted, however, that the gages themselves are not specifically covered under the 3-M System. The gages are a component part of a master or auxiliary system that is covered by the 3-M System. For example, a feedwater system on a boiler has gages. The Instrumentman should be prepared to furnish information, when required, on the maintenance and repair of gages.

Detailed information concerning the 3-M System can be obtained from current editions of publications such as the Maintenance and Material Management (3-M) Manual (OPNAV 43P2) and Military Requirements for Petty Officer 3 & 2 and Military Requirements for PO 1 & C.

FOLLOW LOGICAL SEQUENCE.—Almost any job is more successfully accomplished if it is done in a logical and organized way. In repairing pressure gages, the logical sequence to follow is usually:

1. Inspect the gage for gross damage.
2. Disassemble the gage.
3. Clean all gage parts.
4. Inspect all parts and analyze the nature of the casualty or damage.
5. Replace or repair damaged parts; if possible, manufacture replacement parts.
6. Reassemble the gage.
7. Calibrate the gage.

OBSERVE SAFETY PRECAUTIONS.—Some of the equipment and materials used in an instrument shop are inherently hazardous or can be hazardous under certain conditions. Hazards may include fire, explosion, poisoning, and electric shock. Some important precautions to be observed in connection with pressure gage work are listed and discussed in the following paragraphs.

1. Do not use tools, equipment, or materials with which you are unfamiliar until you have been thoroughly instructed in their safe and proper use.

2. Do not play practical jokes or otherwise engage in foolishness while working in a shop. Men have been killed because someone was "just playing around" with materials or equipment without understanding the dangers involved.

3. Use protective clothing and other safety equipment, when required.

4. Treat mercury with real respect. It is poisonous, and the toxic effects are cumulative. Mercury can be absorbed into the body in three ways: (1) by inhalation of the vapor, (2) by direct absorption through the skin, and (3) by swallowing small bits of metallic mercury with food. Mercury is more dangerous when it is finely divided than when it is in one big glob, since the finely divided material exposes more surface and therefore vaporizes more rapidly. If mercury is spilled, it becomes very finely divided; the small bits lodge in cracks, crevices, and even in the pores of porous materials or surfaces. All of these tiny bits of mercury continue to give off mercury vapor. Small bits of mercury can easily lodge in clothing and shoes and thus be carried off to contaminate some other area. Breathing contaminated air over a period of months can cause serious damage to teeth and bones. Avoid touching mercury continually; it can injure the skin.

Mercury should be stored in sturdy, tightly closed, nonmetallic containers that are clearly labeled. Mercury should be handled in a vented area. When it is necessary to transfer mercury, clear the working area as much as possible. Remove all rings, watches, and jewelry. Prepare a catch pan with a layer of water about half an inch deep on the bottom. Place the catch pan as near as possible under the filling connection. Use a funnel for transferring the mercury; when possible, connect the funnel and the equipment with a length of clean rubber tubing. Pour slowly, and make all adjustments carefully. (NOTE: MERCURY SHOULD NOT BE BROUGHT ABOARD NUCLEAR POWERED SUBMARINES or on aluminum hull ships such as PG and PCH.)

Be very careful to avoid mercury spills. If spills do occur, they must be cleaned up promptly. Provide powerful exhaust ventilation. Gather up as much of the mercury as possible by careful sweeping; use a vacuum line or an aspirator fitted with a water trap to suck mercury out of cracks and crevices. Dispose of the mercury in a safe place (NOT in a trash container).

After spillage, the entire area should be decontaminated by washing it down with a solution of lime sulfur (calcium polysulfide), or a recommended solvent for such purposes, in water. This treatment converts the residual traces of mercury into an inactive, harmless compound.

Do not store food or cigarettes near mercury. Do not eat, drink, or smoke near mercury. After working with mercury or after assisting in cleaning up mercury spillage, check your clothing very carefully for any little globules that may be trapped in your clothing. Wash thoroughly with soap and water as soon as possible after handling mercury.

5. Handle all solvents and cleaning agents, in a well ventilated space, with care. Some are poisonous, some are flammable, and some are both poisonous and flammable. Do not inhale vapors of solvents or cleaning agents. Do not allow solvents or cleaning agents to remain in contact with your skin any longer than necessary.

6. Be careful in using compressed gases. Do NOT under any circumstances direct a stream of compressed air at yourself or at any other person. Do not use compressed air for general cleaning purposes; using compressed air in this way fills the air with dust and can easily blow particles into your own or other people's faces or into delicate equipment.

7. Never allow oil or grease to come in contact with compressed oxygen, since a violent explosion will result. All fittings, gages, lines, and other items used in connection with oxygen systems must be CLEAN for oxygen service—that is, they must be absolutely free of any traces of oil, grease, and other contaminants. NOTE: Gages should generally be clean when received from the manufacturer.) Compressed oxygen is also violently explosive in the presence of hydrogen. Do not allow ANY combustible materials to come in contact with compressed oxygen, since compressed oxygen gives intensive support to combustion.

NOTE: These precautions must be observed with high pressure compressed air, as well as with compressed oxygen.

8. Observe all special precautions required to prevent "diesel effect" explosions in hydro-pneumatic machinery and in high pressure air, oxygen, and other gas systems. It is believed that several very serious explosions in such systems may have been caused by a diesel effect occurring in the Bourdon tubes of pressure gages when the gages were suddenly opened to high pressures (600 psi and above).

What is this diesel effect? A diesel engine operates by taking in air, compressing it, and injecting fuel into the cylinders, where the fuel is ignited by the heat of compression. This same effect can occur in a Bourdon tube if even a very small amount of "fuel"—a smear of oil,

a single cotton thread—is present to be ignited by the heat of compression.

Some of the precautions required to minimize the danger of diesel effect explosions in gages used for high pressure service are: (1) the internal surfaces of the Bourdon tubes of these gages must be thoroughly and completely cleaned whenever the gages are removed for calibration; (2) mineral oil must never be used in deadweight pressure gage testers used for testing high pressure gages; and (3) in some installations, slow-opening valves are used in the lines to gages and to other dead-end parts of the system.

Don't overlook the fact that some of your own gage testing equipment may involve high pressure hydraulic or high pressure gas systems. In addition to observing the required precautions when you are working on high pressure gages, you must observe all OPERATING safety precautions in connection with high pressure liquid or high pressure gas systems. Since operating precautions vary according to the nature and design of the equipment, your best sources of information on these safety precautions are (1) instructions posted at or near the equipment, and (2) manufacturers' instructions.

9. All types of compressed gas cylinders should be handled with very great care. Precautions that apply to practically all compressed gas cylinders include the following: (a) never fill a cylinder with gas other than the one for which the cylinder is specifically designed; (b) never remove or change decals on compressed gas cylinders; (c) never return an empty cylinder without making sure that valves are closed and that protective caps are in place; (d) never drop cylinders; (e) never let cylinders strike against each other; (f) never use cylinders as rollers or supports; (g) never hammer or strike the valve wheel to open or close a valve; use only the wrenches or tools approved for that purpose; (h) never use a cylinder that is improperly marked—that is, where the paint color does not agree with the information on the decal; (i) be careful not to mix full and empty cylinders in stowage racks; (j) never tamper with safety devices on valves or cylinders; (k) never empty a cylinder completely—always leave the recommended amount of pressure which is usually on a decal (where no decal is available, the pressure is usually 25 psi); and (l) observe all special safety precautions appropriate to the various kinds of

compressed gas—oxygen, acetylene, and so forth.

PRESSURE GAGE TEST AND CALIBRATION EQUIPMENT

Devices and apparatus for testing gages (or pressure sensing instruments) include deadweight pressure gage testers, or deadweight gages, portable pressure testers and comparators, panel mounted master gages or indicators, and manometers. Some pressure gage testing equipment makes use of more than one such device.

In using manometers, master gages, or pressure comparators, apply the same pressure to the test device and to the service gage being tested, and then compare the readings. In using a deadweight pressure gage tester, apply a known pressure to the test gage; the pressure is precisely and exactly known because it is applied by means of weights. (NOTE: Weights and testers must be calibrated by a standard laboratory. The deadweight tester, referred to as a REFERENCE STANDARD of pressure, if used correctly, is accurate, and independent of power and other instruments.)

In the sections which follow, two concepts of pressure gage testing are discussed in detail, namely deadweight testing and comparison testing. In general, deadweight testers are considered to be shop or laboratory "REFERENCE STANDARDS," whereas comparison testers are used as a means for calibrating service gages. This, for the most part, places deadweight testers at a level above comparison equipment.

Before any gage is calibrated it should be cleaned either by hand, ultrasonics, flushing, or other means to prevent contamination of the testing system. Various ranges of calibrating equipment for several media of calibrating fluids are discussed later in this section.

Gages for various services are calibrated best with certain fluids primarily to minimize contamination of the gages and to maintain degrees of cleanliness and "dryness" for each class of gage.

A general guide to the type system to be used for various gages, or pressure instruments, is as follows:

GAGE	CALIBRATE WITH
1. vacuum	air
2. compound	air or water

GAGE

CALIBRATE WITH

3. low pressure air	air
4. high pressure air	nitrogen
5. oxygen	nitrogen
6. inert gases	air or nitrogen
7. hydrocarbon gases	nitrogen or water
8. oil and other hydrocarbon liquids	oil
9. steam and water	air or water
10. caisson	air or nitrogen

(NOTE: Sea water pressure indicators should have the Bourdon tube filled with fresh water to reduce the effects of salt precipitating from the sea water and depositing on the outside of the Bourdon tube; this causes corrosion and plugging. Pressure indicators used on viscous liquids like Navy Special Fuel Oil should have the Bourdon tubes filled with a light oil to prevent plugging or sluggish action.) When calibrating gages, use clean dry air; water pumped nitrogen; distilled water; and light, noncombustible, nonflammable oil. Gas gages calibrated on liquid systems must be dried before installation. (NOTE: NEVER USE OIL PUMPED NITROGEN ON OXYGEN OR H.P. AIR SYSTEMS.)

When operating pressure test equipment, the following specific safety precautions should be observed:

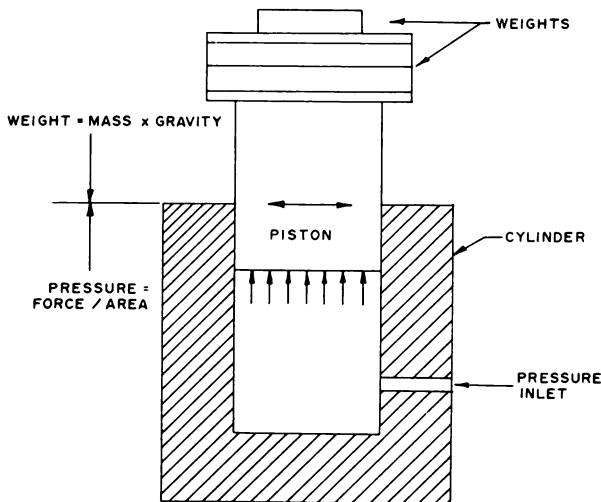
1. Do not exceed the maximum pressure of any gage or tester being used.
2. Do not contaminate water actuated testers by substituting oil or vice versa.
3. Use clean dry air or water pumped nitrogen in low pressure pneumatic calibration systems except where pressure storage cylinders or accumulators are a part of the system. Charge these ONLY with nitrogen.
4. Use only nitrogen or inert gas in high pressure gas systems. Do not use air because of an existing explosion hazard from diesel effect.
5. Do not interchange components between hydraulic and pneumatic calibration systems.
6. Handle "Clean" gages, or those used for oxygen service, and components with care. Clean all parts thoroughly with inert or nonhydrocarbon solvents such as FREON T.F., and test them only with inert gas.
7. Use extreme caution when working with high pressure fluids and high pressure gas.

Rupture or failure of components under high pressure could cause serious injury to personnel.

DEADWEIGHT PRESSURE GAGE TESTERS

In order to advance in rate, you must have a knowledge of the principles of deadweight gage testers. The principle of the deadweight tester is illustrated in figure 6-1. Pressure is measured in terms of fundamental units of force and area. In its simplest form, the tester consists of a piston, of known area, inserted into a close fitting vertical cylinder. Weights loaded on a platform at one end of the piston are supported by fluid pressure applied to the other end of the piston. The pressure produced is the total load of the weights, platform, and piston divided by the cross-sectional area of the piston and cylinder combination. Fluid pressure in the system is developed by either a screw-type ram or a piston pump until the weights are lifted by the pressure, and floating freely in the cylinder. At the same time this pressure is transmitted to the gage being calibrated. A range of calibrating pressure is obtained by adding and removing weight combinations.

The deadweight tester is well suited for calibrating master or standard pressure gages because it not only produces pressure accurately, but also maintains it for an appreciable length



61.122

Figure 6-1.—Principle of the deadweight tester.

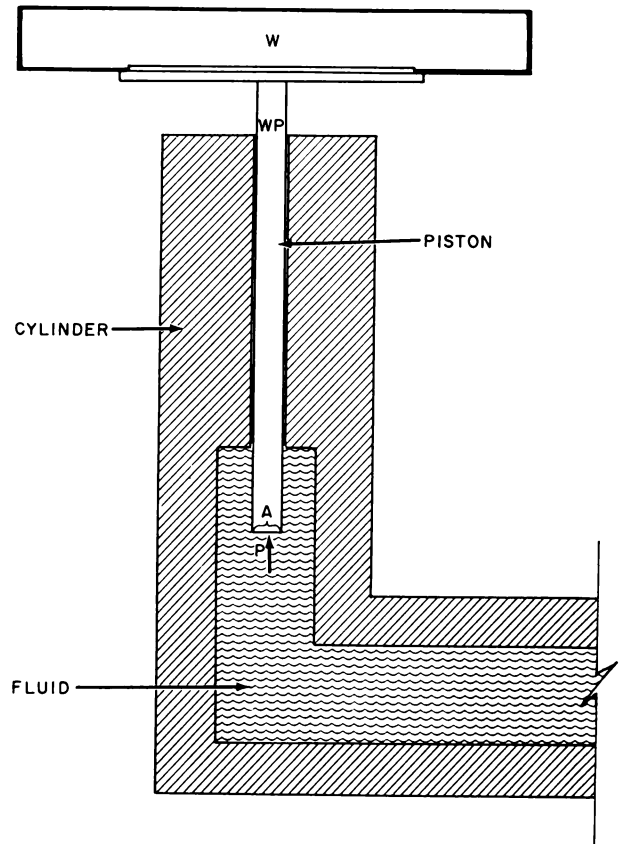
of time, if the system is leak tight and used correctly.

Fluids used with deadweight testers include oil and water. (Air is also used with certain testers.)

Before proceeding with the classification and types of testers used by the Navy, it is best to consider practical applications of the principles of deadweight testers.

Consider the circular piston and cylinder shown in figure 6-2. The piston has some cross-sectional area (A). The total weight of the piston assembly is made up of the weight of the piston (W_p) and any weight (W) placed on top of the piston.

When the force exerted on the bottom of the piston is slightly greater than the total weight of the piston assembly, ($W + W_p$), the piston will be moved up. If this upward force is exactly the same as the total weight of the piston assembly, the piston will neither rise nor fall; it will be in equilibrium.



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Figure 6-2.—Concept of a deadweight tester.

The pressure of the fluid in the cylinder generates a force over the bottom of the piston. The force acting on the bottom of the piston is a function of the fluid pressure and piston area, or $F = PA$ (Force = Pressure times Area). If the system is in equilibrium (piston floating), we can say:

$$W = F$$

where

W = the total weight of the piston assembly
($W + W_p$)

F = the force acting on the bottom of the piston

This is the principle of the deadweight tester. Pressure is applied to the bottom of a piston. If the system can be determined to be in equilibrium, the magnitude of the pressure can be measured by using the expression:

$$P = \frac{W}{A}$$

where

W = the weight of the piston plus any weights on the top of it

A = the cross-sectional area of the piston.

P = the unknown pressure which has established equilibrium

Normally a piston area is selected which will allow weights to be used that are convenient, with respect to the pressure range desired.

Let us assume that a deadweight pressure gage tester has a pressure range to 2,000 psi and it is desirable to have ten separate weights used to generate ten discrete pressures to ten percent increments up to the total pressure. From this information presented, compute a nominal piston area and weight series that will accomplish the required mission.

First, let us consider that we will have ten weights to handle when measuring full pressure. Since these weights must be manually loaded and unloaded from the tester, we want to keep the weights reasonable.

If the piston area were made smaller, it would require less weight to generate a given

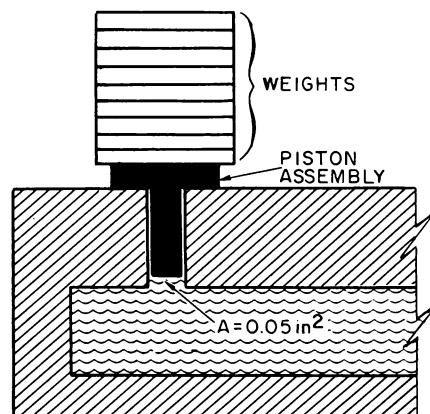
pressure; however, there is a minimum diameter which can be specified for the piston before the tolerance in machining becomes a problem. If we assume that the piston area is one inch square, it would require 2,000 pounds to generate the required pressure; this is impracticable.

Since a diameter of 1/4 inch is easily machined to close tolerance, this piston area is suitable. The complete tester will be as illustrated in figure 6-3. The tester will be made up of ten weights of ten pounds each. Since the piston assembly has weight, it will be desirable for its weight to also be ten pounds; the piston assembly can then act as one of the load weights.

The weight of the piston itself would define and produce the minimum pressure, 200 psi. As each weight is added it will generate an extra 200 psi, until the pressure reaches 2,000 psi, with nine weights plus the piston assembly.

Although simplified, this is the principle applied to deadweight testers. Since each weight operates with a fixed piston area, the weights can be marked to indicate the nominal pressure in psi that they will generate if placed on the tester. The weights of the example given will be marked as 200 psi each, rather than as 10 pounds each.

Let us illustrate the weights which might be supplied with a typical tester. Consider a 10,000 psi unit with a piston area of 0.01 in². Table 6-1 lists the weights available, their serial number, and their nominal pressure (considering the piston area). Notice that the total of all the weight is 100 pounds, which is required when 10,000 psi is generated. The minimum



61.124
Figure 6-3.—Deadweight tester (2,000 psi).

pressure, as limited by the piston, is 100 psi. The resolution, as limited by the smallest weight, is also 100 psi. Thus, any pressure up to 10,000 psi can be generated in 100 psi increments.

Table 6-1.—Typical Weight Denominations

Serial No.	Nominal Pressure (psi)	Weight (lbs)
1	1,000	10
2	1,000	10
3	1,000	10
4	1,000	10
5	1,000	10
6	1,000	10
7	1,000	10
8	1,000	10
9	1,000	10
--	400	4
1	200	2
2	200	2
--	100	1
piston	100	1

Classification and Types of Testers

The four types of deadweight testers generally used by the Navy are the (1) oil or water deadweight tester, shown in figure 6-4, (2) water deadweight tester, (3) bi-fluid deadweight tester, shown in figure 6-5, and the (4) pneumatic deadweight tester. Figure 6-6 shows deadweight gage testers on a miscellaneous pressure test bench of a main shop. From right to left in figure 6-6, the deadweight testers, used for calibrating the MIRCS shop master gages, are the bi-fluid tester having a range of 5-500 psi; individual testers using water as the test medium to 13,000 psi, and oil as the test medium to 10,000 psi.

The oil deadweight tester, designed to operate with oil for applications where water is not suitable, is the most commonly used and generally operates on a light, noncombustible, nonflammable oil. A dual volume hand pump is provided to permit rapid fill of the system. For pressures up to 1,000 psi, the pump delivers a large volume, thereafter a manual shift control enables the pump to deliver a small volume discharge to ease the pumping effort. Two pistons are provided to facilitate low and high pressure work.

The water deadweight tester, similar in construction to the oil tester, operates on distilled water. (To avoid contamination of pressure instruments from conventional oil systems, this tester is designed to operate with distilled water.) The water tester is generally shipped with a small amount of alcohol mixed with the initial water charge to prevent freezing.

The bi-fluid deadweight tester (fig. 6-5) operates with both water and oil. It contains a diaphragm or other sealing device whereby oil on the piston side is separated from water on the gage side. (The bi-fluid tester uses two separate chambers for piston-cylinder and gage tester fluids to eliminate contamination and oxidation as well as to prevent excessive piston wear resulting from foreign matter.) Provision is made for discharging water returning to the tester from units under test to prevent transfer of foreign matter from one unit to the next.

A two-piston hydraulic hand pump is provided to create pressure. One piston volume is approximately eight times larger than the other to allow quick filling of the unit under test. Increasing the pressure automatically inactivates the large piston, enabling the smaller piston to create pressure up to 500 psi.

Both the water and bi-fluid testers are used where oil contamination is to be avoided, such as in the calibration of clean air system gages. Additional information concerning hydraulic tester accessories, weights, tools, and containers can be obtained either from NavShips publications or manufacturers' instruction books for specific testers.

The pneumatic deadweight tester is operated by clean dry air or water pumped nitrogen from an external source. This type tester is used for low pressures (0-30 psi).

In addition to classification by the kind of operating fluid, deadweight testers may also be classified according to the pressure rating. The lowest maximum rating generally used by the Navy is 500 psi. Other common pressure ratings are 2,000, 5,000, and 10,000. The minimum pressure attainable with a deadweight tester is governed by the weight of the piston itself which usually corresponds to approximately 5 or 10 psi. For some testers interchangeable pistons of different diameters are furnished to allow greater flexibility with fewer weights.

Some manufacturers build testers in the superpressure ranges up to 100,000 psi and the very low ranges, such as 0.3 to 1.5 psi, but

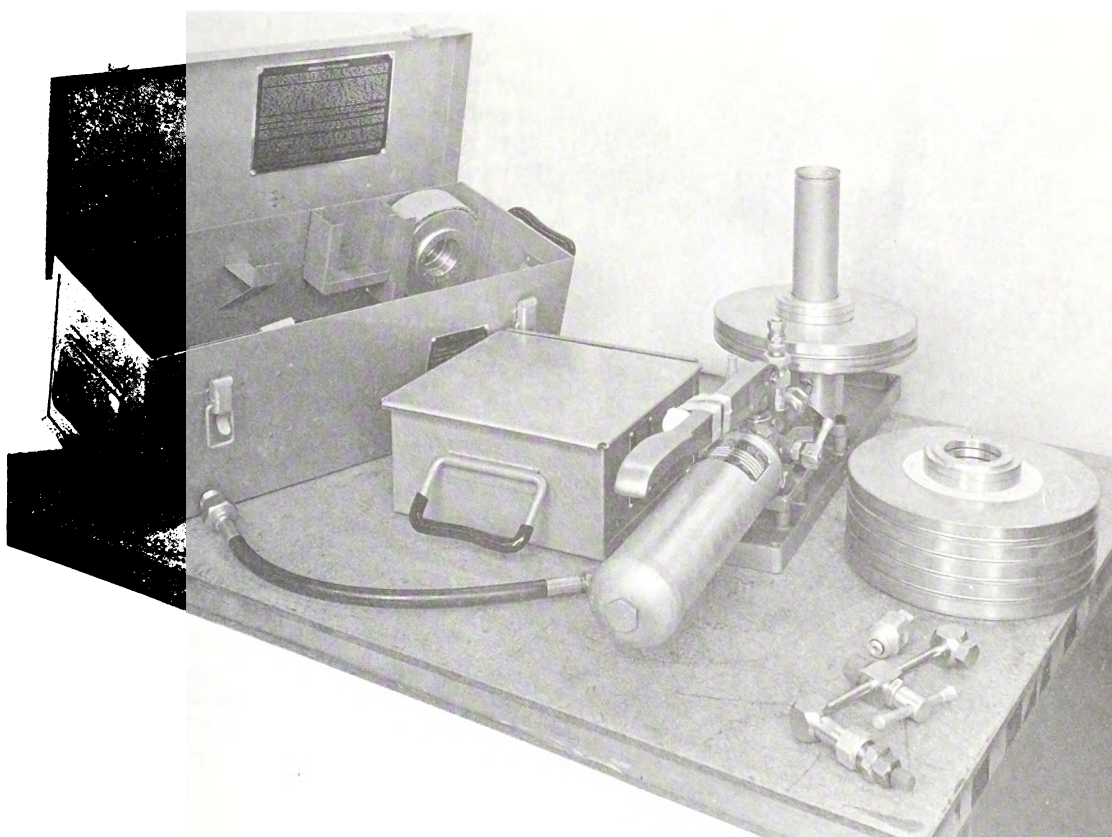


Figure 6-4.—Oil or water deadweight tester.

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these are primarily used in shore-based standards laboratories.

Operation and Factors Affecting Performance of Testers

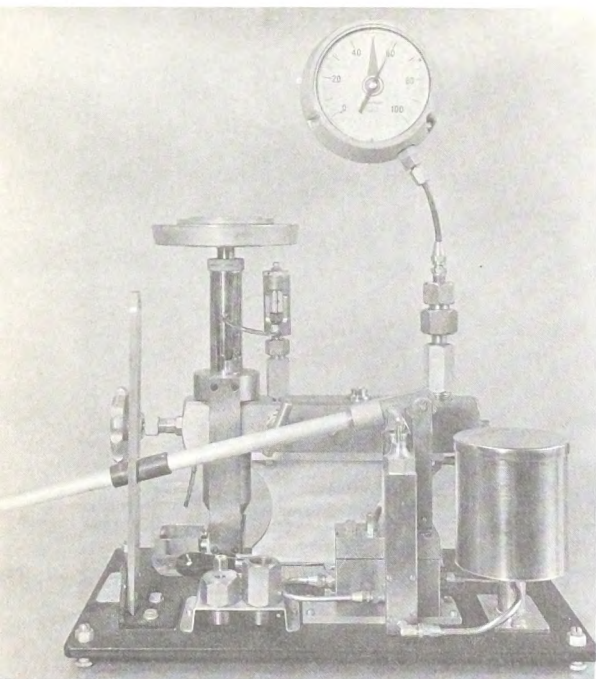
Before using the deadweight pressure gage tester, refer to the NavShips Technical Manual or to the manufacturer's technical manual (if available) for the specific unit in order to become familiar with the operating details of the tester.

The accuracy required of deadweight testers used by the Navy is usually specified to be $\pm$ or $- 0.1$ percent of I.V. or indicated value (the actual pressure being measured). Note that this statement differs from those usually given for pressure gages in that it is a percentage of the measured pressure, not the maximum pressure indicated by the instrument. Weights for

a 0.1 percent tester should be accurate to within 0.05 percent of their designated value.

Limitations on accuracy of deadweight testers are the accuracy of the weight, the tolerance of the piston, the fit of the piston in the cylinder, the actual versus the effective piston area, the stack height, and the diameter of the weights. A low stack height should be used to reduce wearing of the piston and cylinder due to a side thrust on the piston, caused by eccentric loads. Seven inches is regarded as a reasonable height. It is considered good practice to bolt the tester to a solid bench and level the device.

Additional information concerning the operation, accuracy of deadweight testers, and correction factors such as mass of load, effective area of the piston, and head effect can be obtained from manufacturers' technical manuals for specific units.



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Figure 6-5.—Bi-fluid deadweight tester.

Important factors affecting the performance of deadweight gage testers are discussed briefly in the paragraphs which follow. If tester effects are to be minimized and best performance obtained, it is essential that (1) the tester be connected into a leak-tight system, with tubing of the largest bore consistent with strength and safety, (2) the axis of the loaded piston be aligned truly vertical, (3) the weight carefully centered on that axis, and (4) the piston rotated during use. Rotation of the piston serves to spread the lubricant evenly over the entire surface between the piston and cylinder so that there will be no metal to metal contact.

Eccentric Load Error is the most common cause of poor performance of deadweight gage testers. Errors in pressure exceeding one part in 1,000 have been observed. The magnitude of eccentric load error, which has been observed to be a function of the speed, but not of the direction or rotation of the weights, depends on the eccentricity and magnitude of the load, the alignment of the piston, cylinder, and guide bearing, the clearance between the piston and cylinder in the guide bearing, and the leveling of the instrument.

Corkscrewing is an error which may result from a helical scratch or tool mark on the piston, cylinder, or guide bearing of a deadweight gage tester. Corkscrewing is a function of the speed and direction of rotation of the piston. It is usually negligible, but in severe cases may amount to as much as one part in a thousand. Corkscrew error can be reduced by avoiding excessive rotational speed. The user of a deadweight tester should not make all observations with the piston rotating in one direction. Approximately one-half of the observations should be made with the piston rotating in each direction. Then the observer will be able to notice the appearance of a corkscrew error. The observer can, if he desires, average readings taken with the two directions of rotation.

Friction reduces the sensitivity and reproducibility of a deadweight gage tester to a great extent. Excessive friction results from eccentric loading, improper leveling, misalignment of the piston-cylinder-guide bearing assembly, and either excessive or insufficient clearance between the piston and cylinder. Friction in the bearing between the piston and yoke of the suspended, nonrotating load may be excessive.

When the weights are loaded on the piston and set into rotation they should continue to rotate for several minutes. The simplest and most revealing criteria of performance is the coasting time of a freely spinning loaded piston.

When the deadweight gage tester is connected to a leak-tight system and the piston set into rotation, the piston will fall slowly as a result of the leak between it and the cylinder. The rate of fall will depend upon the clearance, length of the crevice, diameter of the piston, pressure, viscosity of the fluid, and concentricity of the piston and cylinder. Re-entrant cylinder type deadweight gage testers should have a fall rate maximum at a pressure about one-half of the range. The fall rates of simple cylinder deadweight gage testers generally increase with pressure. However, at very high pressures most pressure fluids exhibit a very rapid increase in viscosity with pressure so that the fall rate may not increase as rapidly as expected. (NOTE: A fall rate of 0.1 of an inch per minute or greater is indicative of a poor quality deadweight gage tester, and probably unreliable for even routine measurements.)

Fluid Viscosity affects the sensitivity, fall rate, and wear rate. The best viscosity is one that will be high enough for a reasonable fall

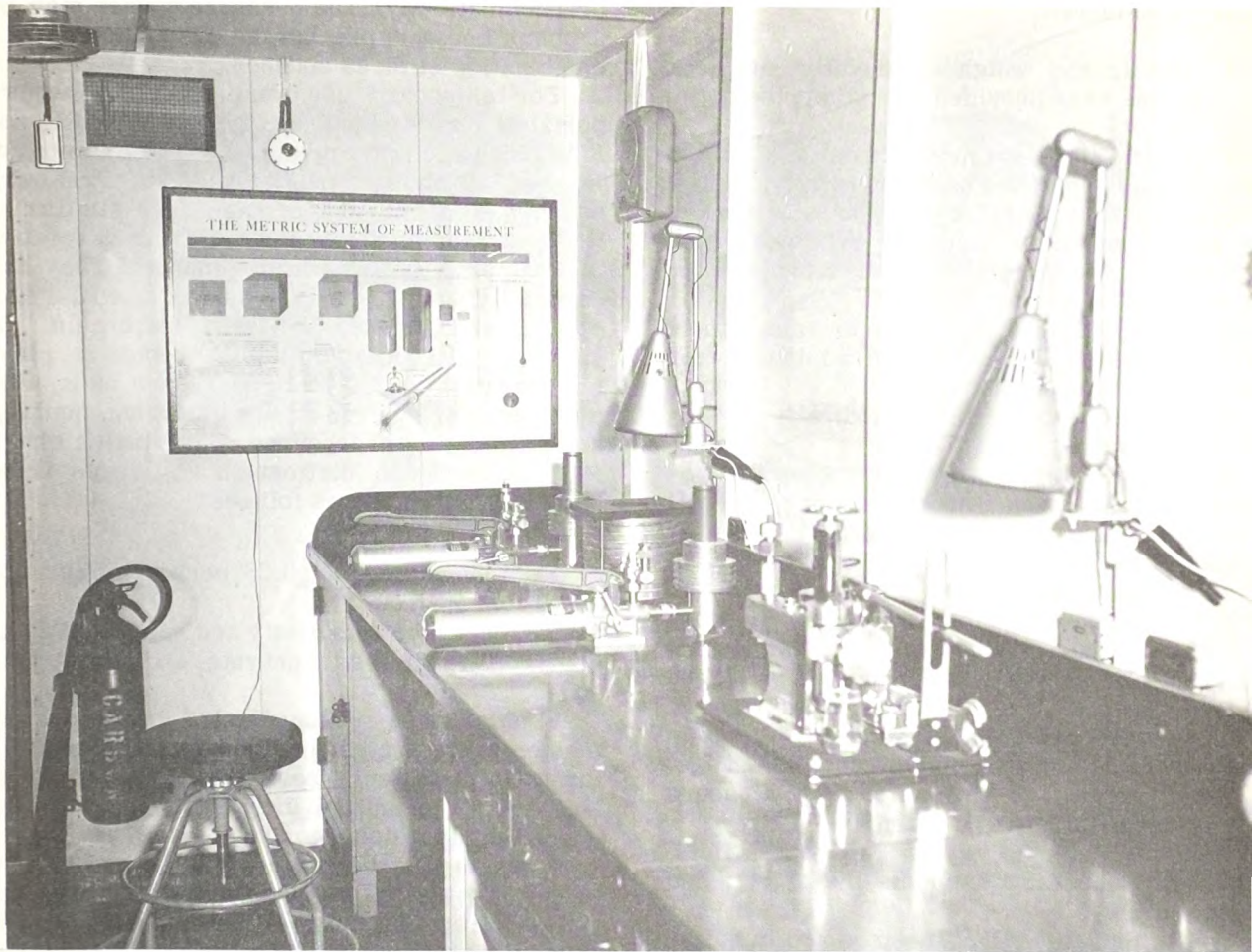


Figure 6-6.—Deadweight gage testers on a miscellaneous pressure test bench (main shop).

61.1

rate but not so high as to make the spin time too short and cause sluggish operation.

As far as Line Restrictions are concerned, long or small diameter connecting lines or other restrictions may result in a significant pressure drop when leaks are present. Small diameter lines are generally not objectionable when the deadweight gage tester is connected to a tightly closed system. When two testers are to be balanced against each other a restriction between them may result in a slow, insensitive operation. This is true to a great extent, particularly when oil is used to transmit the pressure in a unit. An air-lubricated deadweight tester connected to a large volume

system or to another air-lubricated tester may oscillate between the piston stops. The oscillations can be reduced by introducing a restriction in the line to obtain sufficient damping of the system so that a balance can be achieved.

Care and Maintenance of Hydraulic Deadweight Testers

Since the construction details vary for each make tester, the manufacturers' catalog or the NavShips Technical Manual should be read for specific care and maintenance information.

addition, the following factors should be observed and/or considered:

1. Handle the weights carefully and keep them in the case provided when they are not in use.
2. Handle the piston and cylinder assemblies (very accurately fitted parts) carefully. If it is necessary to replace the piston or cylinder, the entire assembly must be replaced. It is impracticable to replace either the piston or the cylinder separately.
3. Do not operate the pump or ram without fluid because it is required as a lubricant for component parts of the system.
4. Flush the reservoir periodically and renew the operating fluid.
5. When operating with water, keep the system free of oil. Even a small amount of oil will develop a scum or emulsion on the deadweight piston and cause a sluggish rotation of the piston. If this occurs, remove the piston and cylinder. Wipe the piston with clean soft paper and work it in the cylinder several times; this will generally clean off the scum or emulsion. Then replace the piston and cylinder in the tester.
6. Replace defective or worn "O" rings in the system. The most common cause of leakage, failure to pump, or failure to hold pressure results from defective or worn "O" rings.
7. If the pump is dry or runs out of fluid, it may be necessary to prime the system and to vent all air.
8. See that flexible connectors are in satisfactory condition and rated for the pressures at which they are used.

Calibration

Deadweight testers are not readily calibrated aboard ship because extremely precise measurements are required. The units are sent to shipyard calibration laboratories or Navy standards laboratories when calibration of testers is required.

MASTER TEST GAGES (PRECISION TRANSFER STANDARDS)

Master test gages are generally used to calibrate pressure gages by the comparison method. Calibration by this method is accomplished by comparing the gage to be tested (the "Test Instrument") with a master (or standard) gage of HIGHER accuracy. Both stationary and

portable systems are used with hydraulic fluids or pneumatically. The pressure source may be a pump, booster, precharged gas cylinder, or a combination of these sources.

For shipboard use, and especially where portability is required, the STANDARD or MASTER gage is the principal working standard. Figure 6-7 shows a master gage kit. Pressure sensing elements of test gages are similar to those of typical shipboard gages as described in Chapter 5 of this training manual. They can be briefly classified as Bourdon tube (C-type, spiral, and helical), bellows, diaphragm, or capsule. Although similar in design to plant or operating gages, test gages are built with much greater control of manufacturing, quality, and calibration procedures. Some major characteristics which distinguish test gages from operating gages are as follows:

1. Accuracies of ± 0.25 percent of span or better.
2. Increased sensitivity and repeatability as compared with less accurate and lower cost gages.
3. Dial sizes are usually $1/2$ inch or larger master gages are very seldom made below $8\frac{1}{2}$ inches in diameter. These gages are also available up to 12 and 16 inch diameters for high precision laboratory work.
4. Instead of the common 270 degree Bourdon tube, some test gage manufacturers build gages with 300 or 360 degree tubes or with double revolution pointers. These gages, especially those with double revolution pointers, have enlarged scale lengths which largely improve readability.
5. On many test gages there are other recognized differences which can be one or all of the following: a mirrored dial face for preventing parallel error in reading (parallax); approximately 12 to 20 adjustable tabs on the dial face for each individual setting of pressure intervals during calibration; bleed tips which permit a thorough flush with solvent, when required; and pressure relief valves or rupture disks to protect gages from overpressure.
6. Temperature compensation to minimize the effect of ambient temperatures on accuracy.

Master gages can be used individually or systematically grouped in various ranges and panel mounted, with as many as eight or ten gages on one panel, for rapid production type

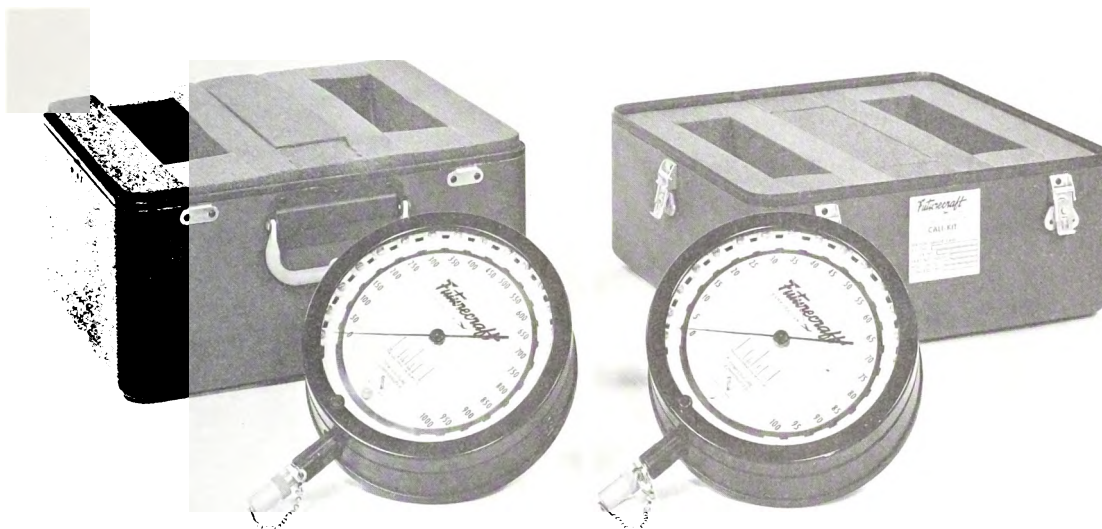


Figure 6-7.—A master gage kit.

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testing. (NOTE: A master gage panel is illustrated in chapter 2 of this rate training manual.) Some portable systems using master test gages are described in a later section of this chapter. In these systems the test gage, used primarily for in-place testing, is combined with a portable pressure source and loading unit. Master gage panels combine regulators, valves, and associated equipment with the test gage for installation in a gage repair and calibration shop. Operating gages are brought, in quantity, to the panel for repair, test, and calibration.

When a master test gage is used for a calibration, the following should be noted:

1. Distinguishing physical characteristics of the test gage as mentioned previously.
2. Test gage accuracy.
3. Date and place of last calibration; check for certification and/or sticker.
4. Type of fluid to be employed; be consistent with oil, water, or gas, and for "oxygen clean (or oxygen service)" gages use clean water-pumped nitrogen only.
5. Exercise greater care in the handling of test gages; their higher sensitivity causes them to be less resistant to shock.
6. Check manufacturers' instruction books, brochures, and test gage literature.

PORTABLE TESTERS AND COMPARATORS

The Navy uses several commercial portable low pressure (as well as high pressure) pneumatic units for in-place testing and calibration of various systems. Four of the most commonly used low pressure pneumatic units are discussed in the paragraphs which follow. (NOTE: Grove comparators are no longer used in installations used by the fleet; therefore, they are not discussed in this rate training manual. Information concerning gas activated comparators can be obtained from manufacturers' technical manuals for specific installations.)

Wallace and Tiernan Portable Pneumatic Calibrator

This instrument is primarily designed for field, or in place, checking and calibration of pneumatic controls and instrumentation which operate in the pressure range of 0 to 24 psi. As shown in figure 6-8, the calibrator consists of a carrying case containing a panel on which are mounted a precision dial manometer, a selector valve, two pressure regulators, an air filter, an air relief valve, and a connection block. A flow diagram on the panel shows all connections between the various components.

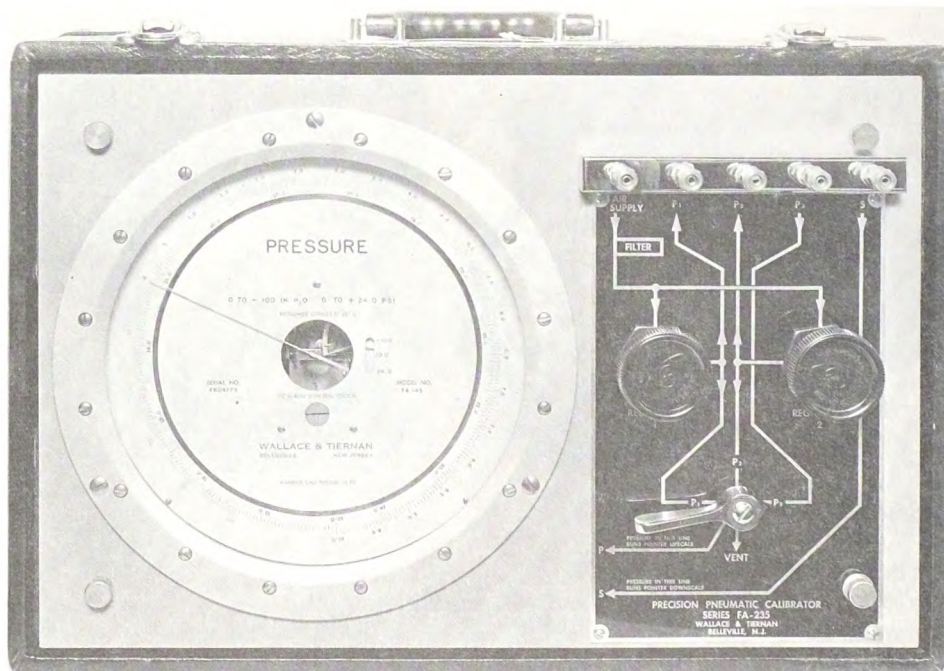


Figure 6-8.—Wallace & Tiernan portable pneumatic calibrator.

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To operate a Wallace and Tiernan portable pneumatic calibrator, proceed as follows:

1. Connect the unknown pressure to the connection marked "P3". Leave S open to the atmosphere.
2. Turn the selector valve to position P3 and read the pressure on the manometer.

Calibrate pressure gages with air by performing the following procedure:

1. Connect a supply of air at a pressure of between 25 and 35 psi to "Air Supply."
2. Connect the gage to be tested to P1 or P2 with flexible tubing or directly into the connection block.
3. Turn the appropriate regulator handle counterclockwise to a completely relaxed position.
4. Turn the selector valve handle to the appropriate position.

5. Turn on the air supply, adjust pressure to the desired value with the regulator, and compare the gage reading with the master manometer reading.

Additional information concerning the calibrator can be obtained from the manufacturer's instruction manual for the specific equipment.

Taylor Pressure Calibrators

As shown in figure 6-9, the calibrator consists of a dial gage, an air release valve, a squeeze-bulb, and flexible tubing for connection to the instrument being tested. The Taylor pressure calibrator is used as an "in place" cross check device, not as a standard for calibration. The two ranges made are 0 to 160 inches of water and 0 to 18 psig. With the air release valve closed, squeezing the bulb forces air to build up pressure in the system being tested. Air is released by unscrewing the air release valve.



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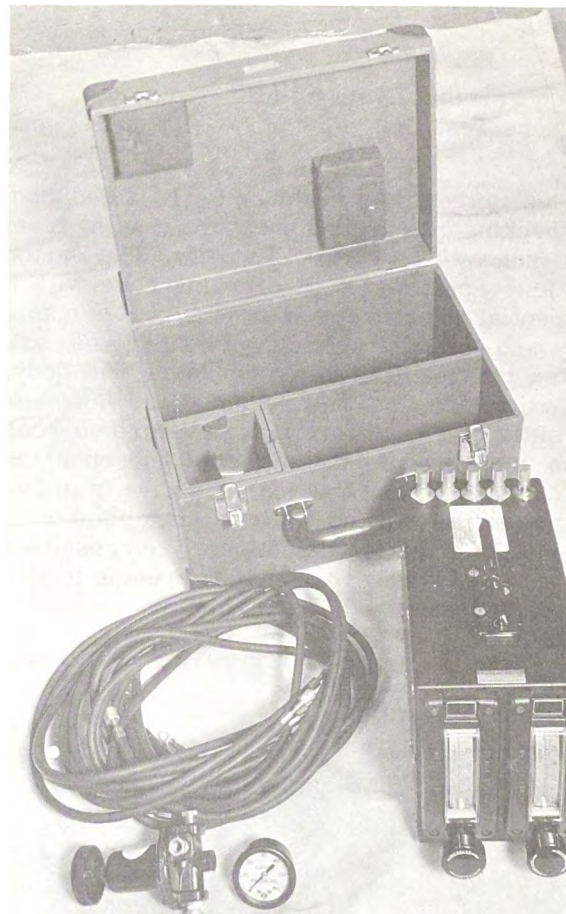
Figure 6-9.—Taylor pressure calibrator.

To operate the unit, proceed as follows:

1. Connect the flexible tubing to the instrument to be tested.
2. Hold the calibrator by the squeeze bulb with the thumb and forefinger on the air valve.
3. Turn the valve counterclockwise to close it.
4. Squeeze the bulb until the dial gage indicates the desired pressure.
5. If the pressure drop is too high, open the valve slightly until pressure drops to the desired value.
6. Return the pointer to zero by fully opening the valve.

Bailey Portable Pneumatic Test Kit

This kit consists of two 0 to 30 psig manual loaders mounted in a carrying case plus flexible tubing, a pressure regulating valve, and a 2 inch pressure gage (0-60 psig) as shown in figure 6-10. The kit can be used for testing various



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Figure 6-10.—Bailey portable pneumatic test kit.

pneumatic devices and setting up control systems involving a number of pneumatic relays and interrupted functions. The Bailey Portable Pneumatic Test Kit can transmit and indicate two pressure signals (0 to 30 psi) and, at the same time, receive as well as indicate two pressure signals from external sources.

The pressure regulator valve reduces ship's air supply to 30 psig where a regulated source is not available.

To test a straight relay, only one loader is used. Connect the input and output from the relay to the appropriate in and out fittings on the kit and connect a pressure source to the input fitting. Load the relay by turning the load knob on the kit. Testing methods for other

systems can be obtained by referring to the manufacturer's manual for the specific installation.

Barton Portable Differential Pressure Test Unit

This unit, shown in figure 6-11, is designed for checking differential pressure ranging from 30 inches of water to 0-400 psig. The Barton test unit consists of a carrying case with a differential pressure unit, a three valve manifold, and flexible tubing. Vent valves are located on the differential pressure unit body.

To operate the unit, connect the high and low sides of the differential pressure sources to be measured to the manifold and open the appropriate valves. Use extreme care in applying pressures so that the test unit pointer is not pegged in either direction. The crossover may be used for zero check by opening it with the side pressurized. Each side may be vented if required.



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Figure 6-11.—Barton portable differential pressure test unit.

In addition to the low pressure units discussed previously in this section of the training manual, the Navy uses several high pressure pneumatic testers and calibrators. Three of the most commonly used units are discussed in the paragraphs which follow.

Futurecraft Calibration Kit

Figure 6-12 shows a futurecraft calibration system with a pressure transmitter. The futurecraft kit is a comparison tester composed of a pressure controller and several master gages. Four gages, having an accuracy of 0.1 percent of full scale, are generally supplied with the following ranges: 0 to 100 psi, 0 to 1,000 psi, 0 to 5,000 psi, and 0 to 10,000 psi. The controller, shown in figure 6-13, consists of a booster pump, pressure accumulator, filter, quick disconnects, pressure relief valves, manual control metering valves, self-sealing vent ports, inlet hose, and outlet hose all packaged in a carrying case. The unit operates from an external nitrogen source of nominally 3,000 psi. It is capable of boosting inlet pressure by a factor of 10 to 1 to a maximum of 12,500 psi.

If the supply pressure is adequate, the boost pump is automatically bypassed and calibration pressure is controlled by two metering valves, one to increase pressure and one to decrease pressure. If the supply pressure is insufficient to calibrate, then the pressure in the 5.37 cubic inch accumulator can be increased by operating the booster pump to the maximum high of 12,500 psi. Since the pump can boost supply pressure by a factor of 10 to 1, at least 1,250 psi inlet is required to obtain the maximum. Therefore, with 1,000 psi inlet pressure, 10,000 psi output pressure may be obtained.

When a limited supply of nitrogen is available, only systems of small volume can be calibrated at pressures requiring a high boosting ratio since nitrogen is used to drive the booster pump and the time to boost is considerable for any but small volumed systems.

A portable, rechargeable, gas bottle may be obtained for the system. It holds 71 scf at 2,200 psi. A fluid separator is also available whereby liquid systems can be calibrated.

To operate the Futurecraft unit, proceed as follows:

1. Connect the inlet hose to the nitrogen supply and the outlet hose to the system to be calibrated. The quick disconnect couplings are

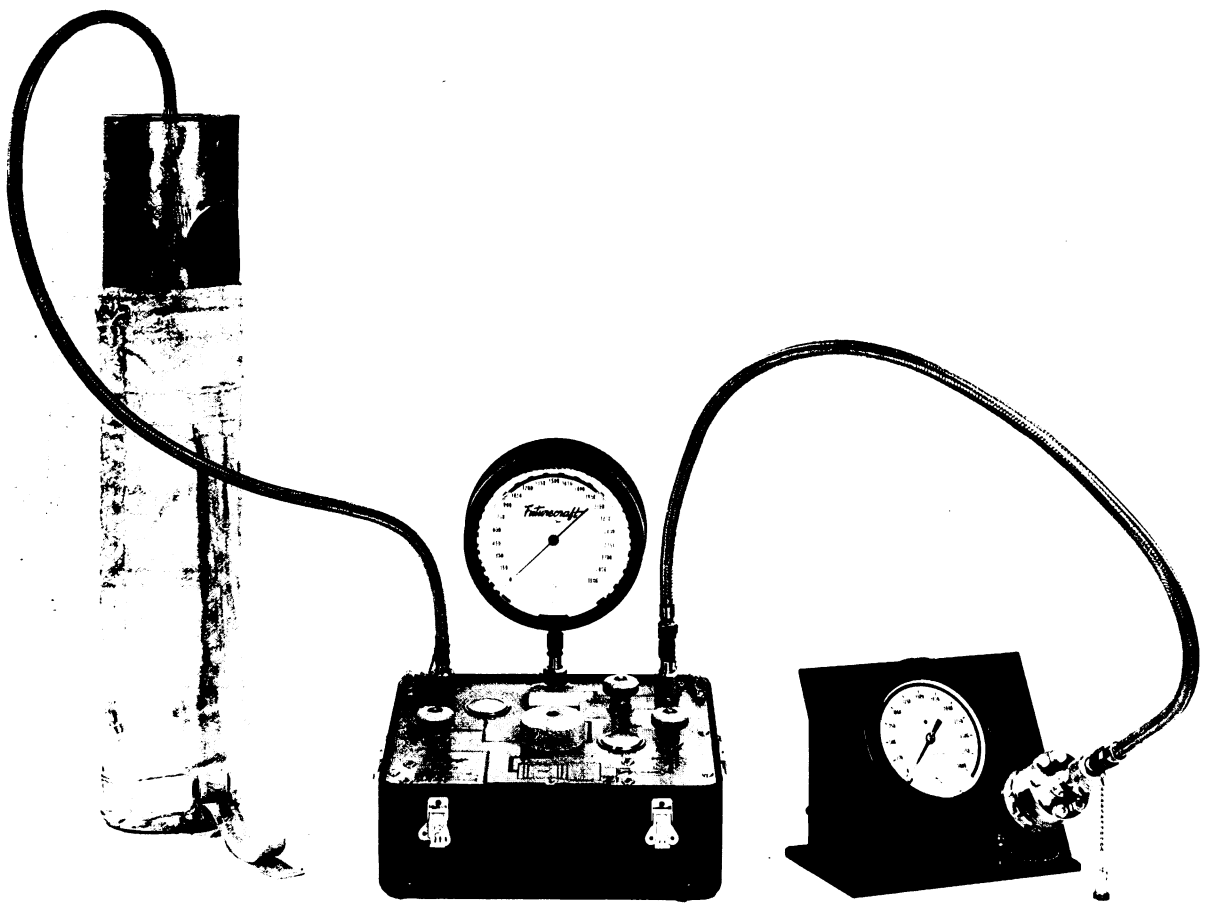


Figure 6-12.—Futurecraft portable calibration system in use with pressure transmitter.

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designed so that those for high pressure cannot be interchanged with those for low pressure. In many cases, adapters are required to connect the hose to the system being calibrated.

2. Mount an appropriate gage at the master gage connection.

3. Open the inlet calibration valve to allow inlet pressure to the boost pump and high pressure side. The position of this valve is normally open during calibration.

4. Operate the booster pump, with the booster valve to pressurize the accumulator when required. If supply pressure is sufficient for calibration, the booster pump is automatically bypassed.

King Nutronics Pneumatic Amplifier

This unit, also a comparison tester, is similar in operation to the Futurecraft controller, except that a master gage is an integral part of the unit. The maximum discharge pressure is 10,000 psi; therefore, the gage range is 0 to 10,000 psi with an accuracy of $\pm 1/4$ per cent of full scale. The major components, shown in figure 6-14, are a boost pump, pressure regulator, vent valve, standard supply and discharge connections, and the master test gage. Appropriate hoses and fittings must be obtained separately.

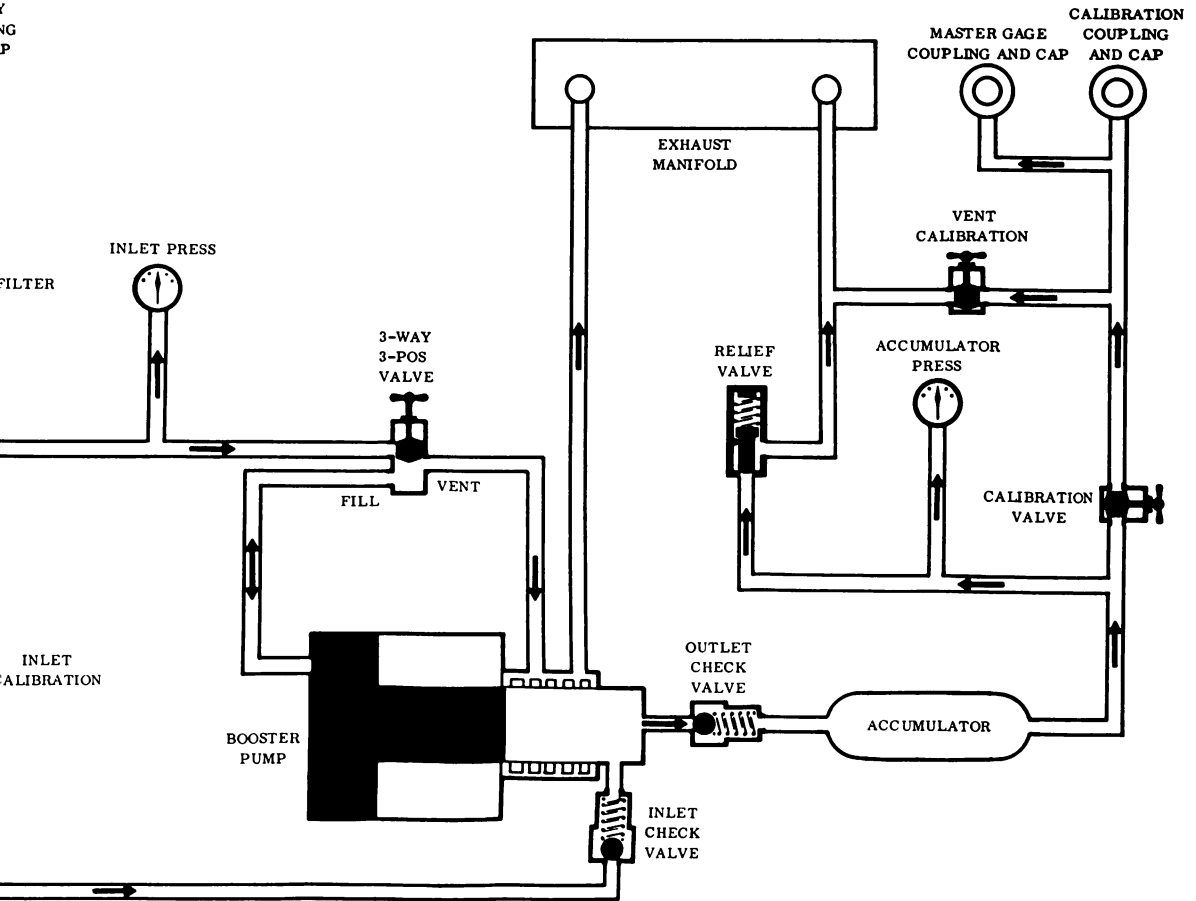


Figure 6-13.—Futurecraft calibrating kit controller.

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King Nutronics Pneumatic Amplifier is connected to an external nitrogen source of 100 psi maximum. This unit can boost inlet pressure by a factor of 5 to 1. As in the Futurecraft unit, it is not necessary to operate the booster pump until the calibration pressure needed exceeds the nitrogen supply pressure. There is no accumulator; the supply or boosted pressure is regulated directly by the master gage and the system being calibrated. Since nitrogen is used for calibration and to drive the boost pump, the operation of the unit depends on the quantity and pressure of the available nitrogen.

To operate the King Nutronics Pneumatic Amplifier, proceed as follows:

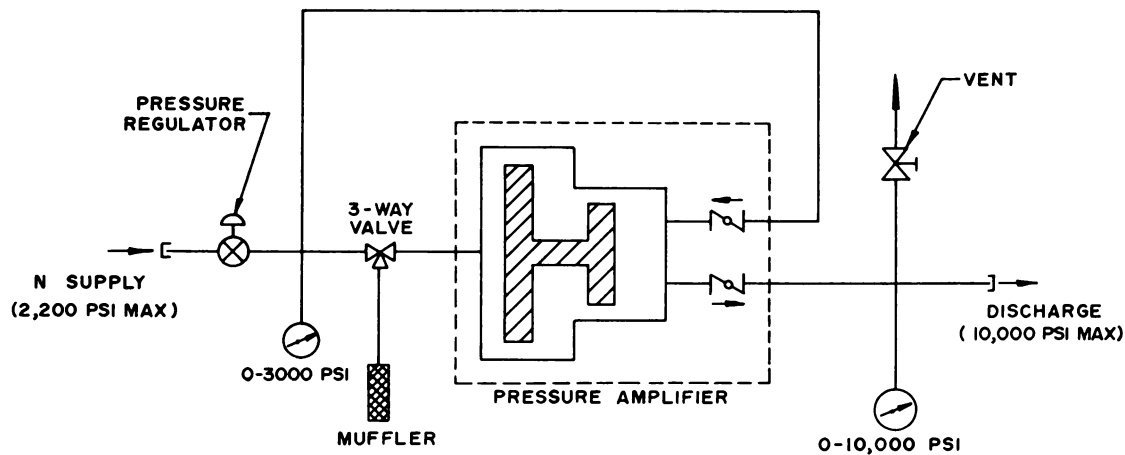
1. Control upscale calibrating pressure with the regulator up to some pressure below the maximum supply. Obtain and control higher pressures with the booster.

3. Control downscale calibration with the vent valve.

Hydraulic Comparator

The hydraulic comparator is similar to a hydraulic deadweight tester except that, instead of a piston and weight assembly, a master test gage is employed. One type hydraulic comparator, specified for military use, is shown in figure 6-15. This unit is designed for operation on light and medium weight oils, water, gasoline, alcohol, kerosene, and glycerine gages.

Connect the supply port to the nitrogen and the charge port to the system to be calibrated.



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Figure 6-14.—Diagram of King nutronics pneumatic amplifier.

pressure vernier. Outlets are provided to which are attached adapters for master test gages and the operating gages to be tested.

On some testers a double volume pump is provided wherein a large volume is used for low pressures, and a smaller volume is used for high pressures. This type unit has a change valve located on the pump body.

To operate the hydraulic comparator, proceed as follows:

1. Arrange the tester in accordance with manufacturer's recommendations or proper operating procedures; this is a general step in preparation for operating the unit. (For in-place testing use the flexible hose to connect the gage being tested.)

2. Select a test gage with a range equal to or greater than the gage being tested.

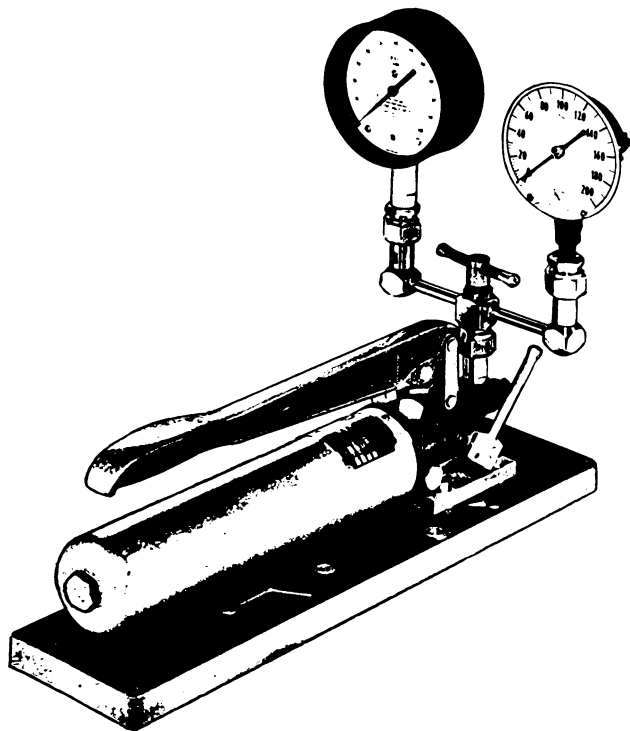
3. Close the relief valve to develop the desired pressure by operating the hand pump. The vent plug should be open about two turns during operation to vent the reservoir.

4. For upscale calibration, pump to practically the desired pressure, then use the vernier valve to obtain the exact pressure.

5. For downscale calibration, reduce the pressure, with the relief valve, then use the vernier for fine control.

STATIONARY TEST EQUIPMENT

This equipment is generally arranged as panel or bench mounted systems located in



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Figure 6-15.—Hydraulic comparator (Mansfield & Green Inc.).

The hydraulic comparator, as shown, is basically a hand pump consisting of reservoir, fill plug, lever, vent plug, pressure relief, and

ibration laboratories or gage repair shops. NOTE: Information dealing with the Repair Department of a repair ship or tender is explained in Chapter 2 of this manual.)

Operating gages are mounted for test on a panel or manifold connected (generally with a flexible quick disconnect hose) to a master test pressure panel, connected to a pressure source. Where vacuum gages must be calibrated, a vacuum pump and chamber are used. For some pressures, manometers are used as master indicators. The major components of stationary systems are explained in the paragraphs which follow.

Master Gage Panels

As previously mentioned, several master test gages may be grouped on one panel according to pressure range and calibrating medium. For example, panels for tender and repair ship mechanical instrument repair and calibration shops (MIRCS) are designated as:

1. Low Pressure Air and Automatic Control,
2. Hydraulic (Water) 0 - 10,000 psi,
3. Low and Medium Pressure Nitrogen (Oxygen Clean), and
4. High Pressure Nitrogen (Oxygen Clean).

The pressure source provided for the panel may be either a shipboard nitrogen or clean air supply, a bottled nitrogen supply, a high pressure nitrogen booster, or a water pump. (Pumps and boosters are discussed in this section.) To operate a typical panel, observe the following procedures:

1. Mount the operating gage(s) to be tested on the test stand.
2. Connect the pressure source and test hoses to the appropriate in and out couplings on the panel.
3. Line up the pressure source valving. All panel valves should be closed. See that the panel inlet valve is closed or the pressure regulator in the UNLOAD position, especially when an initial high pressure (relative to panel comments) is obtainable.
4. Open the valve to the master test gage and open the outlet valve to the test stand.
5. Calibrate upscale and down in the customary manner using a directly pumped or boosted pressure or regulated pressure, whichever is appropriate for the particular panel.

6. On some panels it is possible to conserve high pressure gas by calibrating the highest pressure gages in a group first.

7. When disconnecting flexible connectors or gages from the manifold, see that all pressure is relieved from that portion of the system.

8. Relieve pressure from the entire panel at the end of a calibrating work period.

As mentioned previously, on some panels master test gages may be calibrated in-place on the panel, with their appropriate pressure standards, by closing the test gage valve and connecting the standard to the test outlet. On panels without this feature the master test gages may have to be removed for periodic calibration.

Pumps and Boosters

In this section one specific type of pump and booster selected for shipboard use is described. Although other types may be found aboard ship, the basic principles apply to all pumps and boosters.

The air driven nitrogen booster is a completely piped and self-contained unit consisting of a gas boost compressor, a 20 cubic inch accumulator, and all necessary gages, valves, and accessories as shown in figure 6-16. From a suction pressure range of 800 psig minimum to 2,300 psig maximum the booster is capable of obtaining an outlet pressure of 10,000 psig.

The unit is deck mounted and enclosed in a steel cabinet about 25 square inches with top and bottom access. It is manufactured and should be maintained under "Oxygen Clean" conditions (free of oil, grease, and other organic substances), and free of all loose scale, rust, filings, and other foreign material.

To operate the air driven nitrogen booster, proceed as follows:

1. Open the cooling water valve to the pump.
2. Open the nitrogen inlet valve.
3. Ensure that the vent valve and nitrogen outlet valve are closed.
4. Screw in the air regulator whereby the pump will begin to operate.
5. When the unit has reached a pressure above that of the highest calibration pressure anticipated, allow the regulator to remain turned into that point.
6. Open the unit discharge valve (assuming it is connected to the calibration system) to obtain pressure at the upstream side of the

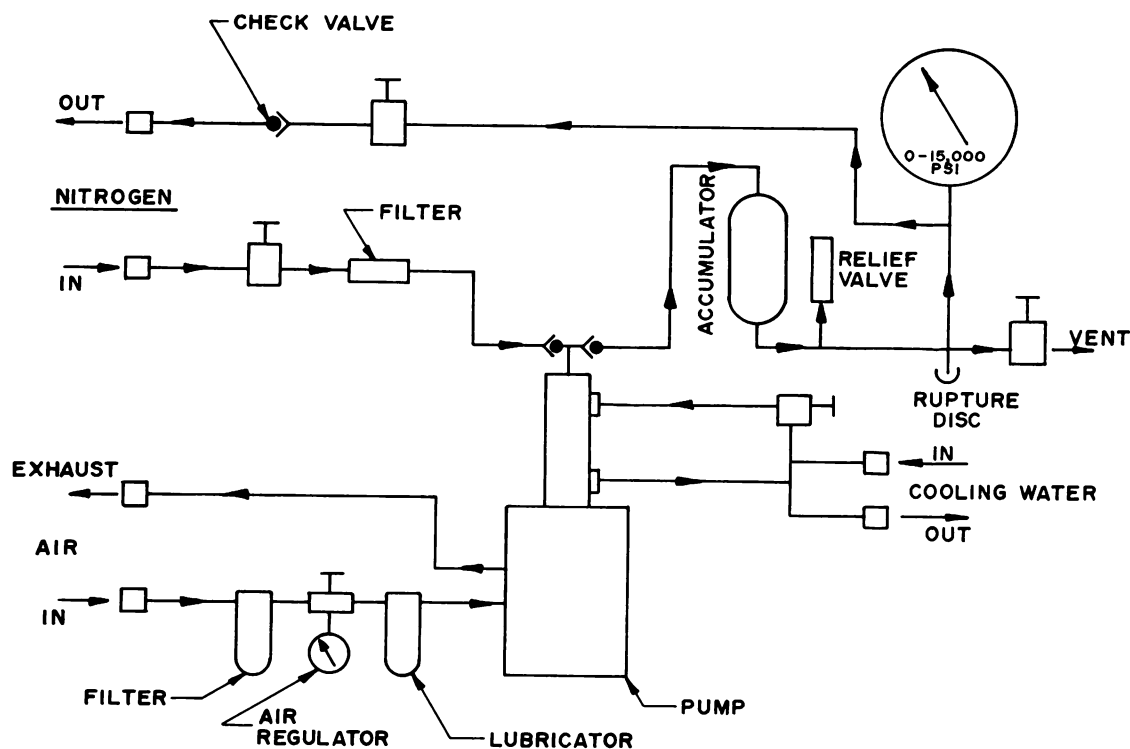


Figure 6-16.—Air driven nitrogen booster.

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calibrating loader being used. The pump will make up the pressure loss automatically and continue to do so as the calibration proceeds.

7. At the end of calibrating, the unit may be secured by closing the nitrogen inlet and outlet valves, turning out the air regulators, and closing the water valve. For day to day calibration, the residual pressure may be allowed to remain in the booster unit, but the calibrating system downstream of the nitrogen outlet valve should be bled off completely.

8. To bleed the unit for periods of nonuse, open the vent valve.

CAUTION—High pressure gas systems are potentially dangerous and should be handled with care and in strict accordance with the prescribed procedure.

Information dealing with hand-operated hydraulic and air driven hydraulic pumps can be obtained from manufacturers' technical manuals for specific installations.

Vacuum and Pressure Chambers

Various chambers are used throughout the Navy. One chamber used in the MIRCSP program is described in this section. Additional information concerning chambers can be obtained from manufacturers' technical manuals.

The vacuum and low pressure chamber, used in conjunction with the low pressure pneumatic test bench, is connected with a vacuum pump, a 0 to 30 inch mercury panel mounted master vacuum gage, a 1 to 1,000 microns electronic vacuum gage, and 0 to 50 inch mercury and water manometers.

The chamber is designed for test and calibration of altimeters, and pressure transducers. The range is approximately 5 microns vacuum to 50 psig. Inside dimensions are 10 1/2 inches wide x 5 1/2 inches high x 12 inches deep with access by a front, quick latching plastic windowed door. Three valves on the chamber are for vacuum, pressure, and vent. To test a vacuum instrument, open the vacuum valve and evacuate

the chamber to the desired points with the vacuum pump. For downscale readings, bleed the chamber with the vent valve. Positive pressure instruments are calibrated by opening the pressure valve and applying desired regulated pressures. Obtain downscale readings with the chamber vent or the regulator vent.

MANOMETERS

From our previous discussion of liquid-column elements in chapter 5 of this rate training manual, it should be apparent that manometers can be readily adapted to the testing of both vacuum gages and gage pressure indicators.

The manometer is a simple, direct pressure instrument in which the measured pressure is balanced by the weight of a liquid column. Since the density and height of the liquid column can be determined with high precision, the manometer is regarded as one of the most accurate of all pressure measuring instruments. In its various forms the manometer is used to measure such pressures as gage, differential, atmospheric, and absolute. It is usually limited to pressures of about 30 psi, for higher pressure ranges, the construction becomes unwieldy. As a pressure sensor the manometer is commonly used for flow metering, liquid level measurement, and specific gravity indication. The U-type manometer is illustrated in figure 6-17.

One means of measuring boiler air pressure is with a well type manometer (fig. 5-3), another is with a boiler draft gage. (The draft gage is usually a diaphragm type pressure indicator calibrated in inches of water. It may be of the duplex type in which case an indication is given of both boiler pressure and smokepipe pressure.)

When manometers are used as test devices, it is sometimes necessary to correct the scales for altitude to compensate for atmospheric pressure. In addition, allowance must be made for variations in the force of gravity at different points on the surface of the earth. Standard correction tables are available. Since most correction tables give the corrections at a standard temperature, a further correction for actual temperature conditions is often required. (NOTE: In order to facilitate reading the scale of water filled manometers, the water in the tube may be colored with a few drops of fluorescein solution.)

MIRCS installations on AR's and AD's have two banks of U-type manometers for test purposes at the low pressure air and automatic controls calibration bench; one bank of manometers goes to 50 inches of water and the other to 50 inches of mercury. On AS's one bank of U-tube manometers and a bulkhead-type aneroid barometer are used instead.

Since the types of manometers generally used, as well as their operation, are covered in chapter 5 of this rate training manual, this information will not be discussed in this section.

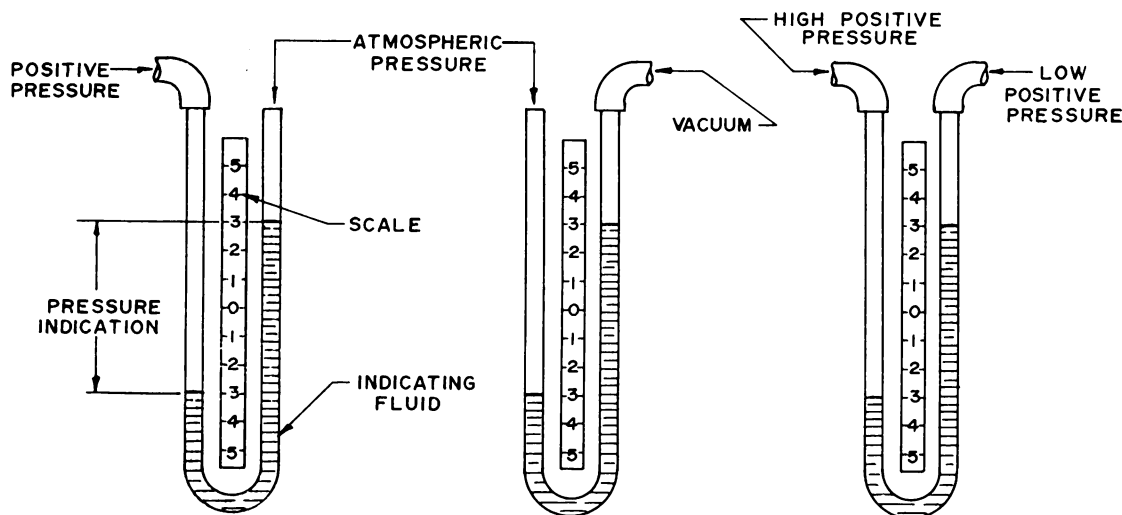


Figure 6-17.—U-type manometer.

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Liquid Factors Affecting Manometers

The manometer is inherently accurate, however, the degree of accuracy depends on factors which affect the indicating liquid used. How important these factors are depends on the accuracy required and the units in which the measurement is expressed.

When using a low specific gravity liquid to measure large units, errors from these factors are negligible. But when using a high specific gravity fluid to measure in terms of extremely small units, the variable factors probably deserve attention. These factors are discussed in the paragraphs which follow.

DENSITY is the most important factor. A manometer can be no more accurate than the known accuracy of the indicating liquid density.

VISCOSITY, which governs fluid flow characteristics, is relatively unimportant in vertical manometers, but more important in inclined units.

SURFACE TENSION results in the interaction of an indicating liquid and the tube walls. This causes the liquid to deflect and assume a curved surface called the meniscus. Liquids which wet the tube such as water and oil have a concave meniscus. Mercury, which does not wet the tube, has a convex meniscus. The smallest bore tubes have the greatest deflection. Water and wetting liquids rise, while mercury drops. This phenomenon in small bore tubes is known as capillary action.

Errors are negligible when acceptable indicating liquids are used with sufficiently large bore tubing. In tubes of 1/2 inch or greater, effects from any fluid are insignificant. In the U-tube manometers, if the two tubes are of the same bore and the fluid above the indicating liquid is the same, the surface tension effects will tend to cancel out in the difference in level, except for hysteresis effects. This can be eliminated by tapping the instrument.

When a vacuum is being measured, the vapor pressure of the indicating liquid should be lower than the maximum vacuum.

All fluids change density with changes in **TEMPERATURE**. Since the most important factor in manometer liquid accuracy is density, temperature must be considered. For extreme accuracy, temperature can be controlled or the mean temperature of the indicating liquid determined, and proper corrections applied to the scale reading.

Care and Maintenance

Keep the tube of a manometer free of dust and dirt. All connections should be tight. If the liquid in the tube is not water, do not permit an accumulation of moisture in the tube. Maintain the required amount of liquid in the tube to keep the levels at the 0 mark when both sides are exposed to normal atmospheric pressure. (NOTE: If condensation of moisture cannot be prevented, correction must be made for the column of water formed.)

Some manometers have sliding scales. When this type of scale is used, by placing the 0 opposite the level in one tube you can get a direct reading of pressure on the other tube. With this type of scale it is not necessary to bring the level of the liquid up to the zero mark.

Avoid over pressurization of manometers. If the possibility of excess pressure exists, a check valve on a return well should be used on the low side of the manometer.

Occasionally, you may have to replace the tube in a manometer. To do this in the single-tube type, drain the liquid by removing the plug in the bottom of the liquid well. Then remove the excess pressure trap above the glass tube. Loosen the gage frame and remove it from the instrument. Replace the broken tube with a new tube and reassemble the instrument. On the U-type manometer, merely loosen the tube supports and connections, remove the broken tube, and replace it with a new one. Empty the broken tube. Replace the old gaskets with new ones and tighten all joints. Then test the tube unit for leaks. If everything is satisfactory, fill the gage with new or clean indicating fluid and it is ready for service.

CAUTION: Absorption of mercury or mercury vapor over a period of time, through the skin, nose, or mouth, causes mercury poisoning. Although vapor pressure of mercury is relatively low at room temperature, it is a dangerous poison.

If you must remove mercury from a manometer, use caution. Avoid splashing or spilling of mercury anywhere. If spilled on a hot surface, the resulting high vapor pressure increases the poison hazard. **DO NOT INHALE MERCURY FUMES.** Do not allow spilled mercury to remain on the deck; pick it up with a suction hose that has a small, metal nozzle. Dust residual amounts with flowers of sulphur. Do not use mercury in a room with a cracked deck, or a deck covered with loose sheet material.

Calibration of Manometers

The U-tube manometer, when made with uniform large-bore tubing and filled with pure water or mercury, can be considered as a primary standard instrument because its standardization involves only length measurements, temperature, and capillary and gravity corrections. Secondary manometers may be calibrated against a primary standard manometer or by comparison with a low range deadweight gage tester.

MERCURY COLUMNS

When you test or calibrate a gage, as you learned previously, you must apply pressure to the gage at the same time you apply the pressure to a standard gage of KNOWN accuracy and then compare the readings of the two gages. The test gage (standard) used should have an accuracy FOUR TIMES as great as the gage undergoing a test.

Pressure standards which have such high accuracy that they may be used for checking other standards are called REFERENCE, SECONDARY or PRIME standards. These standards for pressure are master deadweight testers (discussed earlier in the chapter) and also accurately calibrated temperature-controlled mercury columns. Both of these standards may be used for testing pressure gages. (NOTE: Reference, or prime standards should be kept free from vibration, shock, thermal variations, and foreign matter.)

Mercury columns are used to calibrate both vacuum and pressure gages, and they are available in various heights, commonly 30 inches. A mercury column shown in figure 6-18, works on the principle that applied pressure is balanced by a column of mercury. The column of liquid is contained in a constant-diameter glass tube whose height is read on a scale behind or adjacent to the glass tube. The height of the liquid column multiplied by the density (mass per cubic volume) is equal to the pressure applied. The mercury column is usually provided with a reservoir (well) of constant diameter, at constant temperature. Because the reservoir is many times greater in area than the tube, the level in the well changes only slightly as the mercury goes up or down.

Graduations of the scale on the mercury column are usually corrected for the transfer of the fluid from the well into the column,

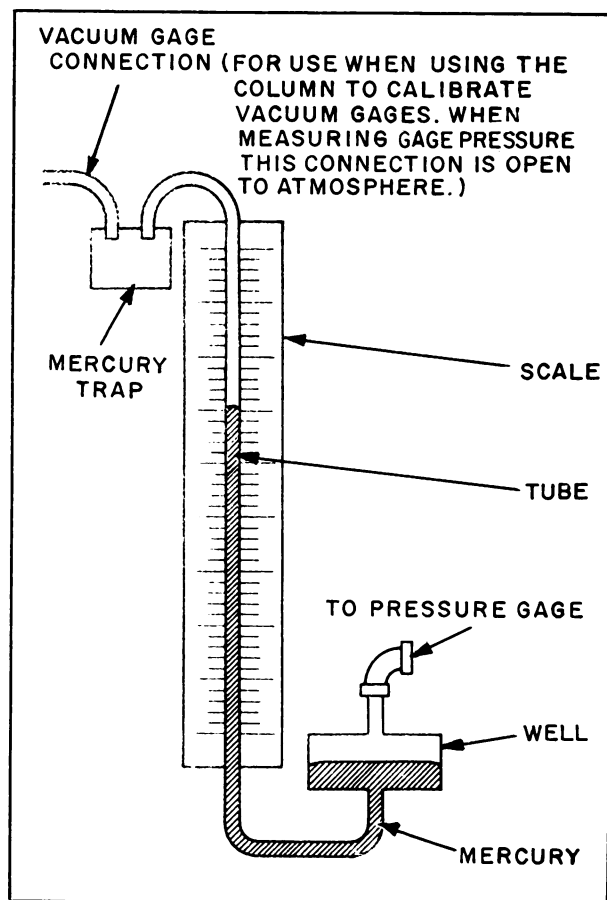


Figure 6-18.—Mercury column. 69.86

because the pressure applied is balanced by the column of liquid whose height is measured from the surface in the tube to the surface in the well.

Accurate mercury columns have corrections made for altitude and latitude to compensate for gravitational effects caused by the earth's rotation. The maximum variation in gravity within the U.S. is .3 percent; from the highest altitude at the equator, the extreme variation of gravity is .6 percent.

Mercury columns must be kept clean, free of dirt, oil, or any other contaminating substance; and the proper level of mercury must be maintained.

The pressures stated in most standard tables, such as altitude tables, are for mercury at zero degree centigrade. A correction is applied to the scale graduations to permit operation at a nominal temperature of 25° centigrade.

The readings are then in mm. or inches of mercury at zero degree centigrade. Readings taken with the mercury temperature above or below the nominal by more than a few degrees must be corrected for the actual temperature. If mercury columns are not set up plumb, measurements with them are erroneous.

The mercury trap serves to catch overflow of mercury.

CAUTION: Mercury is toxic, and it must not enter cuts or the mouth. If you spill mercury, clean it up IMMEDIATELY. If mercury touches brass, bronze, or other copper alloys, it forms an amalgam.

Aneroid barometer testers are also used for measuring atmospheric pressure. Inasmuch as the qualifications for advancement in rating dealing with aneroid barometers are required for advancement to E-6 and E-7, aneroid barometers will not be discussed in this rate training manual. Information concerning aneroid barometers and testers can be obtained either from manufacturers' technical manuals or Instrumentman 1 & C, NavPers 10194-B.

BOURDON ELEMENT PRESSURE GAGES

Bourdon tube gages are precision instruments which require careful handling and proper care and maintenance. These gages should not be subjected to high temperatures, moisture, corrosive fumes, and vibration. Phenol-plastic cases should be used for gages which must be exposed to corrosive fumes and dampness, as these cases do not rust.

The sections which follow deal with routine care, maintenance, cleaning, calibration, and repair of gages. Additional information, not covered in these sections, can be obtained from the manufacturers' technical manuals and texts for specific type gages.

ROUTINE CARE AND MAINTENANCE

Maintenance, cleaning, and repair procedures are similar for all types of Bourdon pressure gages; and most gages are calibrated in accordance with the same calibration procedure. Adjustments are all basically the same, however, they may differ in the way in which they are made because of differences in design used by manufacturers. The purpose of this section is to offer practical guides in handling, maintaining, and calibrating Bourdon tube pressure gages.

After a pressure gage is put into operation, it is necessary to check periodically that the gage is functioning properly and in satisfactory condition to continue to perform its intended use.

The following precautions should be observed when handling pressure gages:

1. Apply pressure slowly. Do not open the gage cock or valve too quickly; this puts a severe strain on the pressure element which may result in rupture or a shorter life.

2. Avoid overpressure. Always set the adjustable red hand, when supplied, to mark the working pressure of the service.

3. When relief valves are used, see that the range of the gage is higher than the set pressure of the relief valve.

4. Avoid sudden pressure release. When the service is subject to sudden pressure applications, use a damper or a gage with a needle valve.

5. See that gages to be used with oxygen or acetylene are kept free from oil or any adhering hydrocarbon. Gages should generally be thoroughly clean when received from the manufacturer. However, if a gage is known or suspected to be contaminated with hydrocarbons, clean the gage, in accordance with current military standards discussed later in this chapter, or replace it with a new or replaced unit.

6. Stow gages where they are protected from moisture and shock. Protect them in instrument cabinets. Tag each gage, and record on the tag the date of cleaning, purpose of gage, and other pertinent information.

Maintenance on Bourdon tube pressure gages is mostly a matter of keeping them clean, the glass intact, and the mechanism in calibration. Periodically, gages should be removed from their mounting, disassembled, and cleaned with a recommended cleaning solution. (NOTE: After a gage has been disassembled, it must be recalibrated. After you clean the parts of a gage, handle them with clean hands, or tweezers, and cloths. Touch edges ONLY: body acid etches the parts. Be careful with the elements, so as not to bend or distort them and thus affect their operating efficiency. When you reassemble a dial gage, install a new felt gasket between the face and the bezel ring. Replace broken faces. Tighten all screws).

Do NOT oil gage movements or linkages. Oil attracts dirt and becomes gummy, resulting in sluggish action and inaccurate readings.

When you install a repaired gage, replace the used rubber gasket with a new one. CAUTION: Pressure and vacuum gages will not indicate properly unless they are correctly installed, and unless their piping systems are airtight. Always apply Teflon Tape to the threads of a new or repaired gage to ensure an airtight installation.

CALIBRATION AND ADJUSTMENT OF GAGES

Inasmuch as the Instrumentman Rating has been largely affected by the Navy Calibration Program, the calibration and adjustment of all measuring instruments has been standardized through the use of Calibration Procedures.

In order to advance in rate, you must be able to repair, adjust, and calibrate simplex, duplex, pressure, vacuum, compound, differential and absolute gages which have elastic chambers.

The discussion which follows deals with the calibration procedure for rotary movement pressure gages 0 to 10,000 psig and the adjustment procedure for rotary movement pressure gages 30 in Hg vacuum to 10,000 psig. Other current calibration procedures, prepared by the Navy, are written for specific pieces of test equipment and pressures. The selection of equipment other than that designated in an individual procedure is the responsibility of the supervisor of the calibrating activity.

Calibration Procedure For Rotary Movement Pressure Gages (0 to 10,000 Psig)

In this procedure, the Test Instrument is compared with the indication of a Standard Gage at selected nominal values throughout the range of the Test Instrument. The appropriate data is recorded on the Calibration Checklist, except in the case of a Qualification where the report form is not necessary.

As far as equipment is concerned, this procedure was specifically developed to utilize calibration panels and test equipment included in MIRCS installations. (NOTE: The Test Equipment must be in its current calibration period.)

To perform the procedure, observe the following steps:

1. Test Instrument Inspection

a. Inspect for cleanliness, damage, mechanical interference, bent pointer, and other defects.

b. Repair obvious defects.

c. Clean the Test Instrument.

(NOTE: If pressure gages are to be calibrated in the MIRCS Clean Room, all gages must be purged internally and inspected in accordance with MIL STANDARD 1330 prior to entering the Clean Room. A "clean" instrument is one which is free of all oil, grease, or other organic materials. The instrument is also free of loose scale, rust, and other foreign matter.)

2. Exercise the Standard and Test Instrument

a. Select the Standard Gage having the lowest range which includes the range of the Test Instrument.

b. Connect the Standard Gage and the Test Instrument to the manifold.

c. Perform the initial adjustments, if necessary.

d. Increase the pressure to the Test Instrument and Standard Gage until the latter indicates full scale of the Test Instrument.

e. Decrease the pressure until the Standard indicates zero.

f. Exercise the Standard Gage and the Test Instrument to the full scale of the Test Instrument two more times.

3. Establish the Starting Point

a. Increase the pressure until the Standard Gage indicates 50 percent of the span of the Test Instrument.

b. Set the pointer on the Test Instrument to indicate this value.

c. Decrease the pressure until the Standard Gage indicates zero.

(NOTE: When calibrating with gas, allow sufficient time for the pressure and temperature of the gas in the system to stabilize after each nominal value is reached.)

4. Range and Linearity Test (upscale)

a. Select five approximately equally spaced nominal values covering the span of the Test Instrument. The first nominal is the first major dial division. The third nominal is the starting point. The fifth nominal is the next to the last major dial division. The second and fourth nominals are located halfway between the first and third and the third and fifth respectively.

b. Record the values in increasing order.

c. Increase the pressure to the Standard Gage slowly.

d. Tap the Standard Gage lightly while approaching the first selected nominal value.

e. Secure the pressure when the first nominal value is indicated by the pointer of the Standard Gage.

(NOTE: The nominal value MUST be approached in the direction of increasing pressure. If the pointer passes the nominal selected, decrease the pressure and repeat steps 4b through 4e.)

f. Tap the Test Instrument lightly and record its indication.

g. Repeat steps 4b through 4f for each remaining nominal value in increasing order.

5. Hysteresis Test (downscale)

a. Record the nominal values selected in step 4 in decreasing order.

b. Increase the pressure in the Standard Gage to slightly exceed the fifth nominal value.

c. Decrease the pressure to the Standard Gage slowly.

d. Tap the Standard Gage lightly while approaching the fifth nominal value.

e. Secure the pressure when the nominal value is indicated by the pointer on the Standard Gage.

(NOTE: The nominal MUST be approached in the direction of decreasing pressure. If the pointer moves past the nominal selected, increase the pressure and repeat steps 5b through 5e.)

f. Tap the Test Instrument lightly and record its indication.

g. Repeat steps 5b through 5f for each remaining nominal value in decreasing order.

6. Repeatability Test (upscale)

a. Record the second and fourth nominal values in step 4 in increasing order.

b. Perform the applicable calibration procedures in step 4 at each calibration point listed for this test.

7. Calibration Test Analysis

a. Determine from the Hysteresis and Repeatability Tests if further repair is necessary.

b. Verify that all recorded values from the Range and Linearity Tests do not exceed the allowable error found in Federal, Military or Manufacturer Specifications.

c. Apply the appropriate label, tag, or both in a conspicuous position on the Test Instrument if it is within specifications.

d. Perform adjustment procedures and make a second calibration run if the Test Instrument exceeds the allowable error.

e. Repeat step 7c.

Adjustment Procedure For Rotary Movement Pressure Gages (30 In Hg Vac to 10,000 Psig)

This procedure, recommended for Mechanical Instrument Repair and Calibration Shop (MIRCS) consists of two sections--INITIAL ADJUSTMENTS and RANGE AND LINEARITY ADJUSTMENTS. For pressure gages that have been disassembled, or had the adjustment broken, it will be necessary to perform the entire procedure. If the gage is new or in satisfactory condition, the initial adjustments do not have to be made; adjustments will start with the range and linearity adjustments. Figure 6-19 illustrates a sketch showing the Range and Linearity Adjustments of a Bourdon tube mechanism.

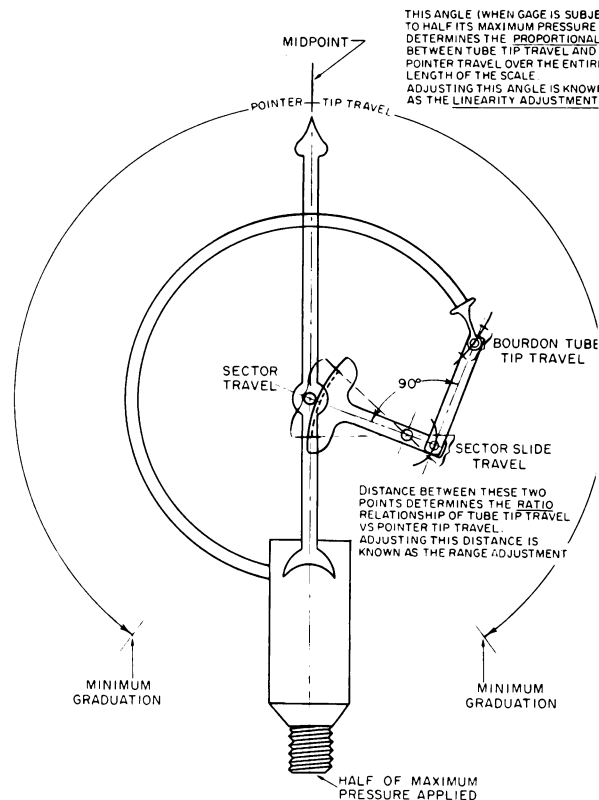
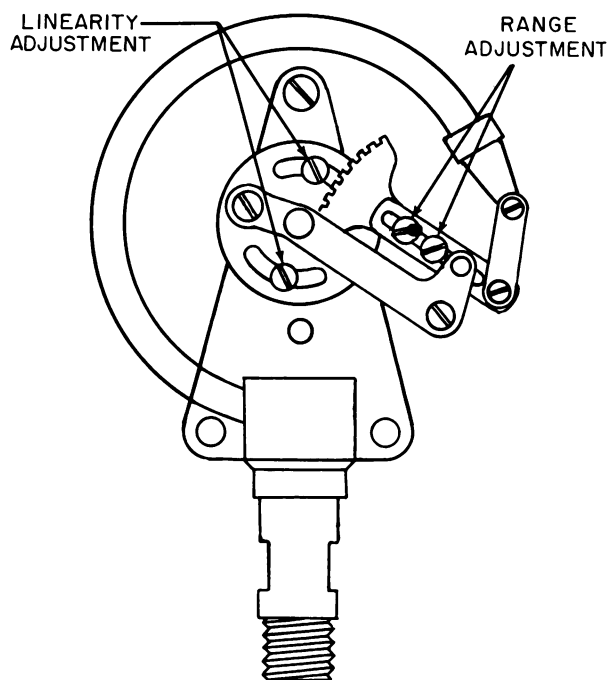


Figure 6-19.—Schematic diagram of the range and linearity adjustments of a Bourdon tube mechanism.

The linearity and range adjustments of rotary and nonrotary pressure gages are shown respectively in figures 6-20 and 6-21.

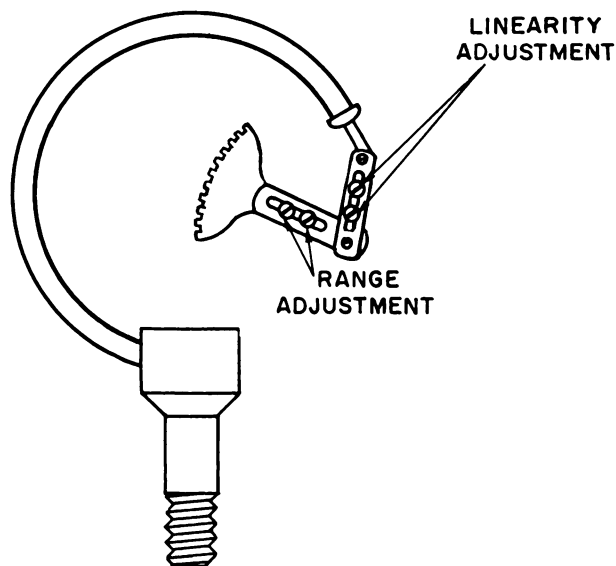
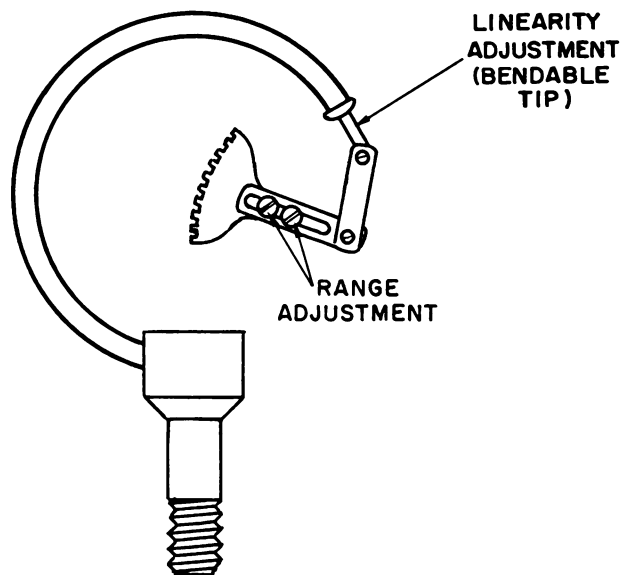


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Figure 6-20.—Rotary movement pressure gage.

Perform the initial adjustments as follows:

1. Establish the RANGE initial adjustment by positioning the sector slide so that it is half-way between its total throw.
2. Establish the Linearity initial adjustment as follows:
 - a. Increase the pressure in the Test Instrument until the Standard Gage indicates 50 percent of the span of the Test Instrument.
 - b. Rotate the movement until a 90 degree angle exists between the connecting link and the sector slide; this is the basis for the STARTING POINT.
 - c. Decrease the pressure in the Test Instrument until the Standard Gage indicates zero.
3. Obtain proper HAIRSPRING TENSION as follows:
 - a. Remove the connecting link screw at the tip of the Bourdon tube.
 - b. Rotate the tooth sector so that it is completely disengaged from the pinion.
 - c. Rotate the pinion 1 1/2 turns in the direction which winds the hairspring.
 - d. Re-engage the tooth sector and pinion.



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Figure 6-21.—Nonrotary movement pressure gages.

- e. Hold the tooth sector and the pinion in mesh and fasten the connecting link to the Bourdon tube tip with its screw.

The result of this adjustment is that tension will always be on the hairspring.

(NOTE: Although the various adjustable parts can be assembled in many positions, the initial adjustments recommended for use will

furnish you a place from which to start the calibration of the gage.)

As far as RANGE and LINEARITY ADJUSTMENTS are concerned, the following runs and adjustments are normally accomplished between the first and second calibration runs:

1. Establish the Starting Point, if necessary
2. Perform the RANGE and LINEARITY adjustment run
 - a. Select nominals one and five from the calibration run.
 - b. Record these nominals on scratch paper. (NOTE: These nominals are used because errors are most evident at these points.)
 - c. Increase the pressure in the Test Instrument until the Standard Gage indicates the first nominal value. Record the Test Instrument indication.
 - d. Increase the pressure in the Test Instrument until the Standard Gage indicates the fifth nominal value. Record the Test Instrument indication.
 - e. Decrease the pressure until the Standard Gage indicates zero.

(NOTE: Don't make large adjustments! Work toward the correct settings with a series of small adjustments. After any adjustment has been made, the Starting Point must be re-established.)

Range Error Analysis and Adjustment

For Loss Error, the Test Instrument pointer travel on both the low and high side of the Starting Point falls short of the Nominal Value being checked. For example, on a 0-100 psi pressure gage, with the Starting Point correct, the Test Instrument indicates 25 psi when it should read 20 psi and 75 psi when it should read 80 psi. This is a LOSS ERROR (RANGE). To correct for a loss error, move the sector slide IN toward the pinion.

For Gain Error, the Test Instrument pointer travel on both the low and high side of the Starting Point exceeds the Nominal Value being checked. For example, on a 0-100 psi pressure gage, with the Starting Point correct, the Test Instrument indicates 15 psi when it should read 20 psi and 85 psi when it should read 80 psi. This is a GAIN ERROR (RANGE). To correct for a gain error, move the sector slide OUT away from the pinion.

Linearity Error Analysis and Adjustment

For a Loss-Gain Error, the Test Instrument pointer travel falls short of the selected nominal on the low side of the Starting Point and exceeds the selected nominal on the high side. For example, on a 0-100 psi pressure gage with the Starting Point correct, the Test Instrument indicates 25 psi when it should read 20 psi and 85 psi when it should read 80 psi. This is a LOSS-GAIN ERROR (LINEARITY). To correct for a loss-gain error, rotate the movement COUNTERCLOCKWISE.

For a Gain-Loss Error, the Test Instrument pointer travel exceeds the selected nominal on the low side of the Starting Point and falls short of the selected nominal on the high side. For example, on a 0-100 psi pressure gage with the Starting Point correct, the Test Instrument indicates 15 psi when it should read 20 psi and 75 psi when it should read 80 psi. This is a GAIN-LOSS ERROR (LINEARITY). To correct for a gain-loss error, rotate the movement CLOCKWISE.

(NOTE: These linearity adjustments apply when access is through the front of the gage. They must be reversed when access is through the rear.)

Combination Range and Linearity Error

The Test Instrument pointer travel will not indicate an equal amount of LOSS-GAIN or GAIN-LOSS on the low and high sides of the STARTING POINT. Correct for a combination error by first adjusting for the most evident error.

Correlate between the Range and Linearity adjustments until the Test Instrument meets the tolerances or specifications as stated in the calibration procedure.

CLEANING PROCEDURES

An important consideration concerning cleaning procedures is the method to be used. Should you clean each part by hand, or should you segregate the parts according to size and clean in an ultrasonic cleaner? Until recently, however, the instrument cleaning (industrial cleaning) machine was used to clean parts, whenever practicable. If the ultrasonic cleaner is not available, it will probably be necessary for ships equipped with cleaning machines to use such equipment to clean instrument parts. Therefore, information concerning these machines is covered in this section.

Bourdon Tube Cleaning Procedures

The following cleaning procedure should be used only on 15 psi gages or those with higher psi ratings. Figure 6-22 illustrates a schematic view of a Bourdon tube cleaning system.

1. See that the threaded connection of the gage is clean.
2. Apply the teflon tape to the connection as follows:

- a. One thread back, in a clockwise direction stretching so that it conforms to the thread shape.

- b. Overlap by 1/2 turn and press firmly into the threads. (CAUTION: Do not use teflon tape on instruments used in the primary loop on nuclear submarines.)

3. Attach the gage to the three-way valve.
4. With the valve in vertical position, start the vacuum pump. The pump is now pulling a vacuum directly on the Bourdon tube. Allow the valve to remain in this position for approximately 1 minute.

5. Turn the valve to a horizontal position. This allows the evacuated Bourdon tube to be filled with Freon TF solvent. Atmospheric pressure is forcing the Freon into the tube. Allow sufficient time for the tube to be filled with solvent.

6. Shake the gage vigorously. This allows the solvent to act on all surfaces of the Bourdon tube. Continue to shake the gage for approximately one minute.

7. Turn the valve handle to the vertical position. The contaminated solvent will then be drawn into the discharge bottle. Turn the gage upside down, then right-side up. Leave the valve in this position for approximately one minute.

8. Repeat steps 5 through 7 of this procedure until the solvent coming from the gage appears to be clean.

9. Remove the bottle of contaminated fluid from its stand and replace it with a "Clean" bottle.

10. Repeat steps 5 through 7 until you have a sample of Freon TF solvent in the bottle.

11. Remove the bottle of solvent and compare it with a fresh sample of Freon TF solvent under an ultra violet light using the procedure which follows.

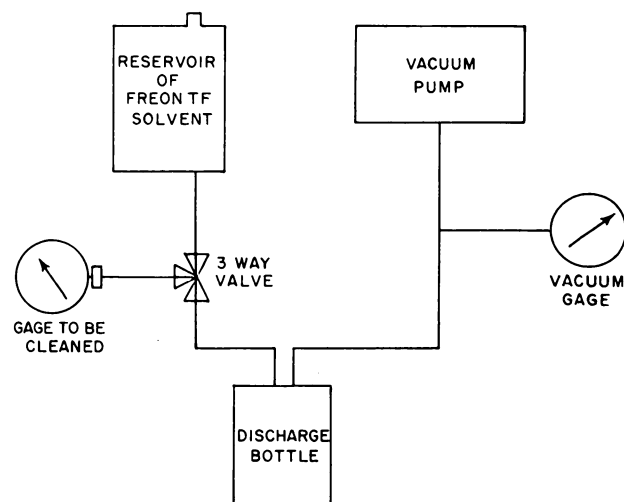
1. Turn the switch to the ON position.
2. Allow about five minutes for the lamp to reach full brilliance.
3. Make tests in a darkened area, as contrast is best with a dark background.
4. Place the object or fluid to be inspected under the lamp. (NOTE: It is preferable to evaporate the solvent over a hot plate and analyze the residue.)
5. If contamination is present, repeat the cleaning process. (NOTE: Oil contaminating the TF solvent appears white and must be compared with a clean sample of the solution. Oil contamination on metal appears white or yellow. Clean metal surfaces show up as violet.) Fluorescent contamination may be bright or dim, depending on the amount present.
6. Secure the switch.

Remember that the lamp housing and filter become hot during operation and care should be taken not to touch them.

Hand Cleaning

The recommended procedure for cleaning by hand is as follows:

1. Initially clean the bushings, pivots, and gear teeth with a pegwood stick.
2. Immerse the parts in the approved cleaning solvent.



Contamination Inspection Procedures

Using a Longwave Ultra Violet Lamp (Model B-100), perform the following procedure:

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Figure 6-22.—Schematic diagram of a Bourdon tube cleaning system.

3. Scrub dirt and gummy residue off the parts with a bristle brush and solvent.

4. Lay clean parts on a clean dry rag to absorb the excess solvent.

5. Dry parts off carefully with low pressure air. Do NOT use air pressure to dry hair-springs. Allow delicate parts such as the hairspring to air dry.

6. Check the bushings and pivots for gummy residue. Clean bushings with a piece of sharpened pegwood. Clean pivots with a piece of pithwood.

Machine Cleaning

If it becomes necessary to use the machine cleaning method, which is also faster than the hand cleaning method, you will discover that most parts can be cleaned at the same time.

Figure 6-23 shows a large cleaning machine with the basket and trays which fit in it. Note the three wedge-shaped trays (one with divider) and the separating cover beneath them. If these trays are put in the bottom of a large cleaning basket and the cover is placed over them, other parts can then be put on top of them in the basket before it is secured in the machine.

Study the diagrams in figure 6-23 which show how clock parts should be placed in the trays and the basket for cleaning. Follow these instructions.

Do NOT overcrowd parts in cleaning trays. Parts should not contact each other in a manner that impedes good cleaning.

To clean parts, use the following procedure:

1. Place the parts in wire basket (s) of an instrument cleaning, or industrial cleaning machine. (Do not overcrowd the baskets, if more than one basket is used.)

2. Snap basket(s) in place in the cleaning machine.

3. Fill the cleaning machine cylinder to the correct height with a recommended cleaning solution.

4. Immerse basket(s) of parts in the cleaning solution.

5. Turn switch to ON position and run the machine for three minutes. NOTE: If the machine has a timing device equipped with an alarm, set it for a three-minute run.

6. Raise the basket of parts out of the cleaning solution and spin it (in the machine container) a few moments to eliminate excess cleaning solution from the parts. Then lower

the basket into the first rinsing solution and spin it for one minute. NOTE: Eliminate excess rinsing solution from the parts in the same manner you used to eliminate the cleaning solution. Do not allow parts to remain in the solution too long because they may become etched.

7. Remove the basket of parts from the first rinse and spin it for one minute in the second rinse.

8. Remove the basket of parts from the second rinse and spin it for at least four minutes in the drier. NOTE: It is best to turn on the drying chamber of the machine as soon as you start to clean parts, so that the chamber will be hot when you need it.

9. Remove the basket(s) from the cleaning machine and remove the parts using tweezers. When handling clean parts, use tweezers or hold them by their edges to avoid having body acid etch the parts and spoil the finish.

10. Check the bushings and pivots for gummy residue. Clean the bushings with a piece of sharpened pegwood. Clean the pivots with a piece of pithwood.

Ultrasonic Vapor Degreasers and Cleaners

Ultrasonic vapor degreasers and ultrasonic cleaners were originally used to clean teleprinters, adding machines, typewriters, and duplicators. They are now used by the Navy to clean hydraulic filters, mechanical instruments, electronic components and systems, and a great variety of metal, glass, plastic, fiber, and rubber parts. These cleaners remove oil, grease, oxides, rust, heat scale, and carbon. Ultrasonic cleaning systems employ high frequency mechanical vibrations transmitted into a suitable cleaning liquid. The part to be cleaned is immersed in the liquid where the cleaning action occurs. A countless number of small but intense impacts erode the surface soil from immersed parts. This action is called cavitation which wears away surface contamination; it does not shake off the dirt.

An ultrasonic unit, whether a vapor degreaser or a simple cleaner, consists essentially of a generator and a transducerized tank. The generator converts electrical line energy to high frequency energy which is then supplied to the transducers on, or in, the tank. The transducers transform the high frequency electrical energy into acoustical (or mechanical)

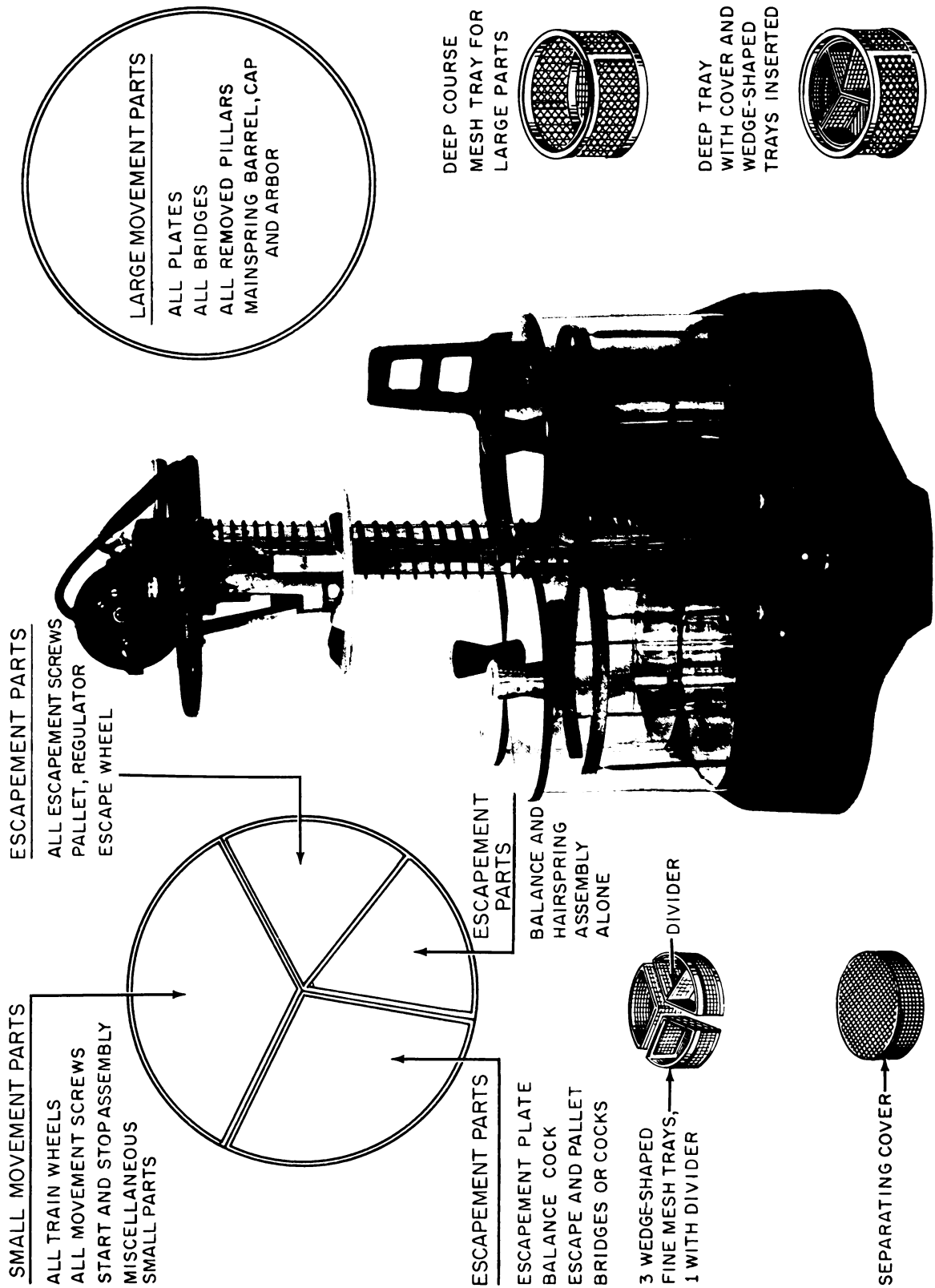


Figure 6-23.—Cleaning baskets of an instrument cleaning machine.

energy and transmit it into the solution. The acoustical energy, in the form of pulsations, results in compression and expansion of the solvent or solution in the tank and produces a phenomenon known as cavitation.

Cavitation means "formation of a cavity." The cavities referred to are bubbles in liquid. Bubbles can be formed around a small pocket of gas, a piece of dirt, or even a smaller bubble. These are the nuclei of the bubbles which remain in an inactive state until some thermal, mechanical, or chemical change occurs. This change upsets the equilibrium of the nuclei; this disturbance is caused by the transducer.

The transducer is either epoxy bonded or silver soldered to the tank. The method is determined by the type of transducers used. The transducers are usually installed in groups, when size permits, and spaced throughout the tank to give optimum results. The transducers may be bottom mounted or side mounted external to the tank or immersed in the solvent or solution. Additional information concerning transducers and associated equipment can be obtained from the manufacturer's instruction manual or NavShip publication, if provided, for the specific installation.

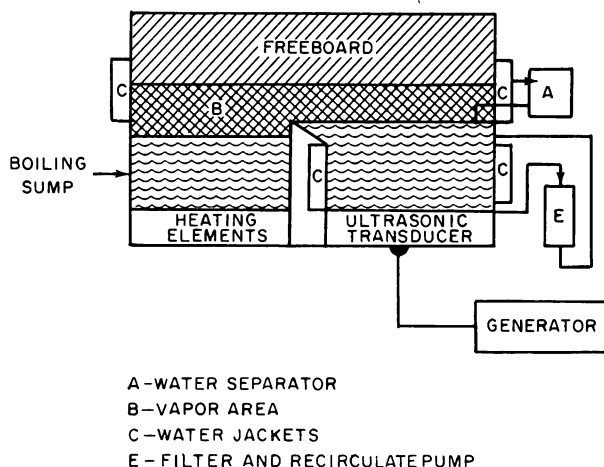
As far as cleaning systems are concerned, vapor degreasers differ from ultrasonic cleaners primarily in that they use a solvent solution which must pass through a vaporization-condensation cycle where ultrasonic cleaners generally use an aqueous detergent solution with water rinse and a drying tank. Because the methods are different, the major components required to perform the task also differ.

The following components, shown in figure 6-24, are required in a vapor degreaser:

1. Boiling sump
2. Heating unit
3. Ultrasonic sump
4. Generator
5. Transducer
6. Water jacket and/or cooling coils
7. Water separator
8. Recirculator and filter

The following components are required in an ultrasonic cleaner:

1. Cleaning tank
2. Generator
3. Transducer
4. Heating unit



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Figure 6-24.—Typical ultrasonic vapor degreaser.

5. Rinsing tank
6. Dryer

A vapor degreaser has the solvent in the boiling sump brought to its boiling point by the heating unit. Boiling produces concentrated vapor which blankets liquid surface areas and is condensed by the water jacket and/or cooling coils. After condensation, liquid solvent enters the water separator which removes water condensed from air during cooling. Pure distilled solvent then flows into an ultrasonic sump where cavitation occurs. Constant overflow of solvent back into the boiling sump completes the cycle.

The operating of an ultrasonic cleaner is based on the same phenomenon of cavitation activity as a vapor degreaser. The primary difference in operation is that with the ultrasonic cleaner, cleaning is performed in a tank (cleaning) in which the oscillations set up by the transducer are used to cause cavitation in an aqueous detergent solution. Although the solution is heated, no boiling or condensation occurs. After items are removed from the cleaning tank, they are immersed in the rinsing tank where the detergent solution is removed by water. After being rinsed, the items are dried in a heated chamber.

The normal amount of associated equipment such as controls, thermostats, pumps, and timers are used with both types of units to ensure maximum operating efficiency.

ING AND TESTING BOURDON "C" GAGES OF OXYGEN AND GEN PIPING SYSTEMS

much as you may work with oxygen and n gas piping systems, you should know clean and test Bourdon tube pressure of such systems. In accordance with y Standards, MIL-STD-1330 (SHIPS), the ng cleaning procedure is recommended eeder type Bourdon "C" tube pressure

Disconnect the indicators from the cyl- or high pressure piping if they are known defective or if they have failed a gage ation test.

Remove the back of the indicator, care- elongate the coil of the capillary tubing to the free tip of the tube outside the indi-

Open the capillary by filing off the tip notching and bending no more than 1/8 f the distal portion.

Immobilize the indicator in a horizontal on supported by a ring stand and clamp so e exit port of the capillary bleeder drains into an Erlenmeyer receiving flask.

Adapt a length of teflon tubing properly to the threaded entrance port of the indi- and connected to a 1/4 inch of glass tube ling below the level of the cleaning solvent ned in a 250 milliliter (ml) suction flask. Connect an air pressure line to the side of the suction flask. The incoming air d be passed through a scrubber containing ng solvent to remove any trace of hydro- ns which may be admixed with the air y system.

Place 150 ml of cleaning solvent in a n flask.

Adjust the incoming air pressure (5 psig) mit a flow rate of approximately 50 ml per e to force the cleaning solvent through the tor connection and out of the bleeder exit n the collecting container.

Repeat with two additional 125 ml por- of cleaning solvent.

Introduce 50 ml of cleaning solvent gh the connection of the indicator and t effluent in a clean white porcelain dish. rate to dryness and check for fluorescence a long wave ultraviolet light (3600-3900 om units). If no fluorescence is discern- the indicator is free of hydrocarbons. Con- flushing if fluorescence is evident.

11. When the indicator is free of hydro- carbons, disassemble cleaning apparatus and force dry oil-free nitrogen (certified by the laboratory) through the indicator and out the bleeder port to remove the last traces of the solvent.

12. Reseal the tip of the capillary bleeder by welding. Carefully recompress the capillary coil to clear the indicator cover and mechanism.

13. Test the pressure gage with dry oil-free nitrogen to ensure proper working order prior to installation.

14. Replace the cleaned indicator into the high pressure system maintaining oxygen clean conditions at all times.

(NOTE: An approved procedure other than the preceding one, may be specified by the chemical laboratory to clean and test Bourdon "C" tube pressure gages.)

REPAIR AND INSTALLATION

Normal repair of gages consists mostly of replacing broken crystals and damaged pointers. However, all reusable parts in a gage should be salvaged for later use, if necessary. Pointers should rest about 1/16 inch to 1/8 inch above the dial, and you may have to ream out the hubs of some types in order to get them to fit properly on the spindles. Therefore, you must handle pressure gage parts carefully.

The most common casualties and their remedies are listed and included in the information which follows:

1. Excessive wear of parts (lost motion): replace parts or gage.

2. Damage to internal parts: replace parts or gage.

3. Corrosion of internal parts: clean or replace parts.

4. Bind in moving parts: clean or replace parts.

5. Inaccurate readings resulting from binds (locate and eliminate), faulty hairspring (adjust or replace), and calibration error (recalibrate).

6. Sticky or sluggish action caused by dirty gage (clean the gage) and improperly adjusted hairspring (repair the spring so that it is true in flat and round).

7. Ruptured or deformed pressure element: replace the assembly, if available, or replace gage.

8. Threads on pipe connection damaged: (a) chase threads with an appropriate die nut and (b) replace assembly or gage.

9. Case broken: replace case or gage.
10. Gage window cracked: replace the window.
11. Loose or bent pointer: replace or repair pointer, as necessary.
12. Illegible dial: replace dial.
13. Deformed snap ring: straighten or replace ring.

As far as installing pressure gages is concerned, common sense is the most important ingredient. Wrenches are used on gages only where the maker has supplied flat surfaces on the socket for this purpose. The crushing effect of pipe wrenches is well known; do not use them on gages. The case of most gages is fastened to the socket; a wrench applied to the case will remove and ruin the gage.

A gage which has provision for adjustment through the back of the case is rather difficult to calibrate, if mounted on a wall. However, a gage subjected to severe vibrations is much better off mounted on a rigid wall with connections made to it through flexible tubing. The tubing should be long enough so that it can be coiled a turn or two, or vibration will break it. No gage should be installed so that piping strains must be absorbed by the socket. The best installation will use flexible tubing for the final connection.

A steam gage must be installed so that only water will enter the gage; otherwise the allowable temperature on the Bourdon tube will be exceeded. To ensure this protection, install a siphon in the line leading to each steam gage. The best form of siphon is a complete turn in the pipe, commonly referred to as a coil siphon. The siphon must be of sufficient capacity to fill the Bourdon tube with water when pressure is applied. Siphons must be exposed (not insulated) so that the steam may be condensed before it reaches the gage.

All steam gage connections should be led from the top of the pipes. Boiler gages should be connected to the highest part of the shell or drum and vacuum gages connected to the top of the condensers.

All pressure gages, except the 2 1/2 inch dial steam mounted type, must be mounted on a gage board. Do not attach the gage board to the operating machinery nor to anything likely to vibrate. (Gage and gage boards should be mounted so that vibration of the gages is minimized.) Gages mounted on gage boards must be mounted on truly flat surfaces and have

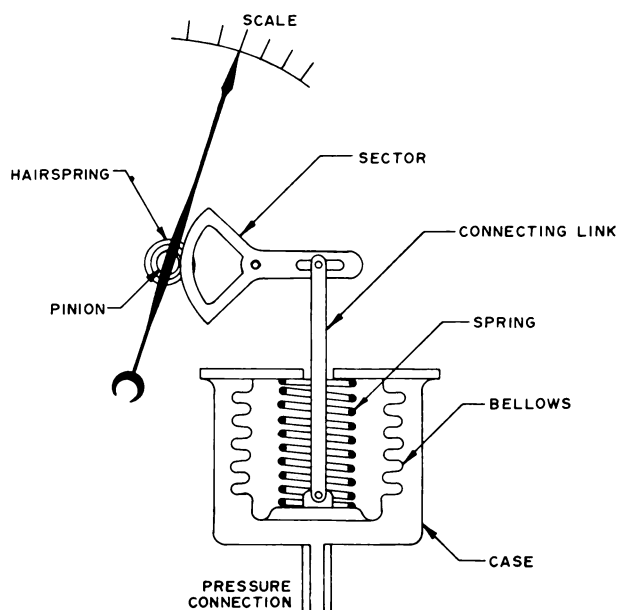
a resilient rubber washer at least 1/16 inch thick on each securing bolt between the gage case and the gage board. Exercise care to see that the case is not warped by tightening of the securing bolts.

BELLOWS ELEMENT PRESSURE GAGES

A bellows gage (discussed in chapter 5) is generally used to measure pressures below 15 psi, which are less accurate than the range of a Bourdon tube gage. Some bellows gages are satisfactory for measuring draft pressures and for general low pressure measurements.

The bellows gage (fig. 6-25) uses an elastic chamber formed with two or more welded diaphragms or a formed bellows. Motion of the element in the bellows gage, as well as the diaphragm gage, is transmitted by suitable linkage and gears to a dial pointer.

The sensitive indicating mechanism of a bellows gage should be protected as much as possible when the gage is not in use. New gages should be kept in original cartons until they are installed. Periodically, check gages in service with a gage tester, and perform such other maintenance on them as necessary. Follow instructions in manufacturers' technical manuals for disassembling, cleaning, and adjusting.



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Figure 6-25.—Bellows gage.

Because the bellows of some gages are made of resilient metal, they have lasting qualities; they should be kept clean and free of foreign substances which may corrode or damage the mechanism.

Before you adjust a gage, check it for cleanliness and working condition. Check the hairspring to determine whether it has sufficient tension to take up all lost motion from minimum to maximum travel of the pointer. When there is a proper balance between the travel and speed adjustment of the pointer of the gage, it is calibrated and should read accurately.

To calibrate a bellows gage, you must check and adjust the travel and speed of the pointer, as necessary. The procedure for doing this follows.

For travel adjustment, you generally use a deadweight tester or an accurately calibrated temperature-controlled mercury column to raise the pressure on the gage to a point equivalent to its middle pressure. Then put the pointer in the position necessary to indicate this pressure. Increase the pressure to the maximum graduation on the gage dial and check the pointer. If it is on the low pressure side of the maximum graduation, loosen the sector screws (fig. 5-22) and push the sector slide in until the pointer registers on the maximum graduation. Retighten sector screws. If the pointer registers pressure beyond the maximum graduation, release the sector screws and pull the slide out until the pointer registers on the maximum graduation and retighten the screws. The purpose of this adjustment is to get the pointer to read correctly at half pressure and at full pressure.

For speed adjustment, you check the reading of the hand at intervals of pressure from the first major graduation on the dial up to the maximum. If the gage reads correctly for the first half of the dial but slow for the last half, loosen the lever screws (fig. 5-22) and shorten the lever span. Do this by moving the lever toward the bellows. If this gage reads fast for the last half of the dial, lengthen the lever span by moving the lever away from the bellows. Retighten the lever screws when you have the speed adjustment correct.

DIAPHRAGM PRESSURE GAGES

A diaphragm gage is sensitive and often used to measure air pressure in the space

between the inner and outer boiler casings. This type of gage is usually designed by the manufacturer in accordance with specifications for a specific purpose and is calibrated accordingly. This does not mean, of course, that further adjustments may not be required when the gage is installed on a piece of machinery.

Both metallic and nonmetallic diaphragms are used in these types of gages. (Refer to chapter 5 of this training manual of a description of the diaphragm elements.) Diaphragm elements are generally used for low pressures ranging from 0 to 1 inch of mercury to 0 to 30 psig. These elements are also used for measuring low vacuum as high as 30 inches of mercury and pressure to 200 psig.

For pressures in the range of 10 psig, diaphragm gages are generally considered superior to Bourdon spring and bellows gages. Motion of the diaphragm may be quite small—about 0.1 inch. Therefore, the gage requires a high quality, frictionless movement to translate the diaphragm motion into motion of the indicating pointer. However, with a relatively large effective area, the diaphragm develops many more times the pointer torque (turning force on the pointer shaft) than a Bourdon spring at the same pressure.

Typical applications for diaphragm gages include low pressure absolute pressure gages, draft gages (to be discussed later in the chapter), pneumatic receiver gages, liquid level gages, and differential pressure gages.

CARE AND MAINTENANCE

Check all diaphragm gages frequently to determine whether the zero adjustment is correct. Each gage has a three-way cock for cutting off the pressure in the line to the gage (fig. 5-26, which shows a nonmetallic diaphragm pressure gage). If you turn the handle of the cock to a right angle with the valve body, the gage unit is open to outside air pressure and the reading on the scale should be zero. If you turn the handle of the cock parallel to the valve body, the gage unit is open to pressure in the line.

You can make a zero adjustment on the gage by turning the zero adjustment screw (5-26) in or out, as necessary, to set the pointer on zero. When you complete this adjustment, turn the cock handle parallel with the valve body to restore pressure against the diaphragm.

Occasionally, diaphragms must be replaced. To do this, turn off the pressure in the line. Then remove the outside zero adjustment screw and the three-way cock and its coupling. Next, remove the unit from the gage case and disassemble it.

To remove the old diaphragm from the unit, compress the small spring on top of the calibrating spring and loosen its retaining pin. Then take out the stem which holds the calibrating spring and remove the screws around the edge of the diaphragm casting. You can then remove the old diaphragm.

Clean both surfaces of the casting. Then apply a small amount of gasket cement to the edge of the lowest casting and immediately place the new diaphragm-gasket assembly over the lower casting's edge. Replace the top casting. Insert screws and draw them up uniformly to ensure a tight joint. Replace the calibrating spring stem. Then compress the spring and insert the pin in the stem that holds the spring in position. Finally, replace the unit in the case. The gage is then ready for service.

Since you may be working with draft gages, as well as other diaphragm type gages, and the information which follows is probably helpful to Instrumentman personnel, draft gages are covered separately in the next section.

DRAFT GAGES

The draft or boiler pressure gage, a diaphragm actuated instrument, is capable of measuring air pressure up to 200 inches of water. The diaphragm, a tough airtight membrane, is made of leather or neoprene impregnated cloth. (These gages are sometimes referred to as nonmetallic or slack diaphragm gages.) The diaphragm is connected to a pointer by suitable links, springs or gearing. The dial or scale is sheet steel or aluminum pointed white with black markings. The case is sheet steel with a glass or plastic face.

A three-way stopcock is provided with each gage so that the instrument may be switched from boiler air pressure to room pressure. This makes it possible to shut off the gage and check the zero reading without disconnecting the piping at the instrument. The

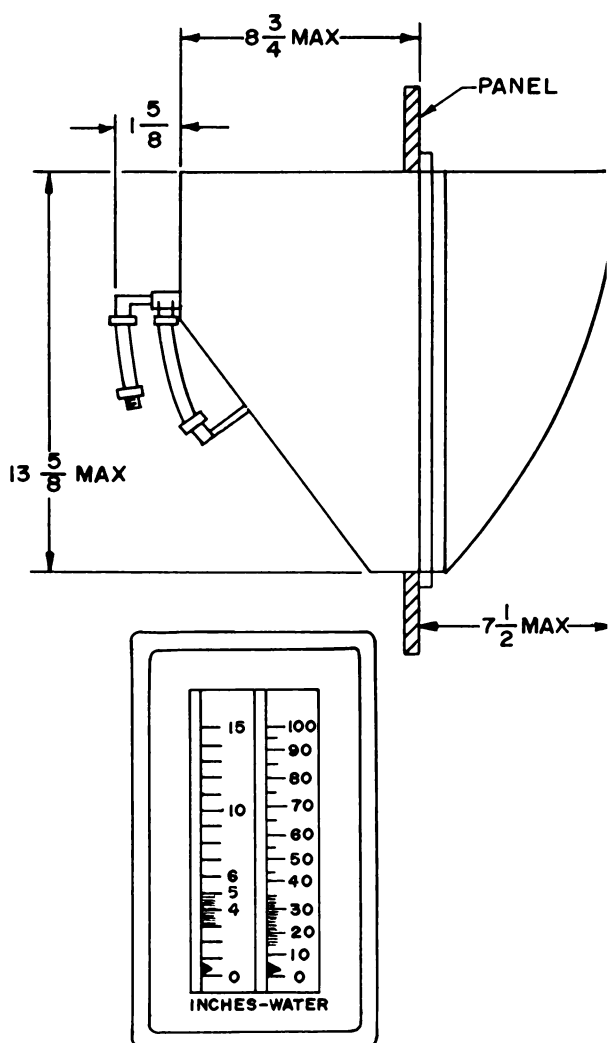


Figure 6-26.—Typical vertical scale type draft gage. 61.14

gage has a 1/4 inch male pipe thread connection.

The three types of draft gages specified for Navy use are discussed in the paragraph which follow.

Dial Type Gages

The dial type gage, similar to the common pressure gage with a pointer indicating on a circular dial, is an 8 1/2 inch size

available in three ranges with the following graduations:

Range Inches of Water	Linear Scale 0-90 Degrees Inches of Water	Linear Scale 90-270 Degrees Inches of Water
0-140	0-10	10-100
0-170	0-15	15-150
0-200	0-15	15-200

Accuracy is within plus or minus one scale division for the 90 degree portion of the scale and plus or minus two percent of full scale for the remainder of the scale range.

Vertical Scale Gages

In the vertical scale type draft gage the actuating mechanism between the pointer and the diaphragm is arranged so that the pointer moves in a vertical plane. Figure 6-26 shows a typical vertical scale type draft gage. The four classes of this type of instrument are as follows:

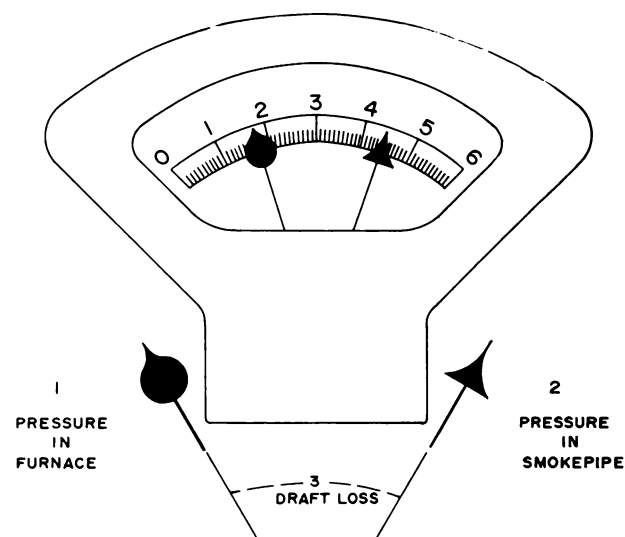
Class 1—Single unit with one indicating scale.

Class 2—Dual unit with a low range and high range scale.

Class 3—Triple unit with a low, medium, and high range scale.

Class 4—Multiple unit with not more than four scales consisting of either four class 1 or two class 2 units.

Accuracy of the vertical scale type gage is within plus or minus two percent of total scale range.



61.146
Figure 6-27.—Window type duplex draft gage.

Window Type Gages

The window type gage (duplex type is shown in fig. 6-27) has a pointer actuated over an arc of not less than 65 nor more than 180 degrees. The usual ranges are 0 to 26 inches or 0 to 50 inches of water. Accuracy is within plus or minus two percent of total scale range.

CHAPTER 7

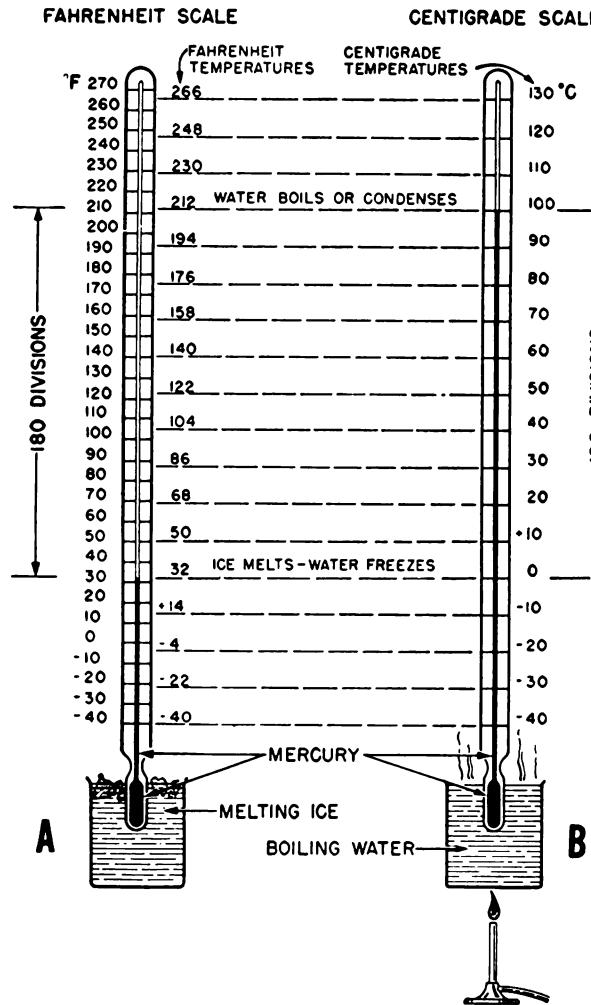
TEMPERATURE MEASURING DEVICES

Temperature is defined as the "degree of hotness or coldness of a substance measured on a definite scale." Hotness and coldness are the result of molecular activity—the faster the molecules of a substance move, the more heat it contains; heat being a form of energy. When two substances possessing different quantities of heat come into contact with one another, heat flows of its own accord from the substance at a higher temperature to the other with a lower temperature. (The kinds of energy and heat transfer are discussed in chapter 4 of this rate training manual.)

The comparison of heat content of one substance with another is made by reference to temperature scales. These scales also make it possible to measure and identify the heat level when there is a change in the state or condition of the substance.

The temperature scales most commonly used (discussed in chapter 4 of this training manual) are the Fahrenheit and the Celcius scales. On both of these scales the freezing temperature of water and the boiling temperature of water are used as fixed points. On the Fahrenheit scale the freezing temperature is 32° F and the boiling temperature is 212° F with 180° between the fixed points. On the Celcius scale the freezing temperature is 0° C and the boiling temperature is 100° C with 100° between the fixed points. Figure 7-1 illustrates the temperature scales. (NOTE: A comparison of temperature scales including Rankine and Kelvin is shown in figure 3-1 of this rate training manual.)

This chapter discusses how thermometers and pyrometers are used for various temperature measuring functions aboard ship, the principles on which these instruments work, and the amount and type of maintenance you will be required to perform on them in the instrument shop. Before you can qualify for advancement to Instrumentman 3, for instance, you must be able to convert temperatures from Celcius to Fahrenheit, test the calibration of separable socket thermometers, and maintain thermometer test equipment.



33.11(61)
Figure 7-1.—Temperature scales. A. Fahrenheit. B. Centigrade (Celcius).

The instruments used aboard ship for measuring temperature include:

1. Direct reading thermometers—liquid-in-glass or bimetallic types.
2. Distant reading thermometers—indicating dial types.
3. Pyrometers.

A thermometer is an instrument which measures temperature. The temperature measured may be that of air in a room, water in a washing machine or storage tank, brine in an ice machine, oil and bearings in a machine, or of substances in many other locations. In general, a thermometer measures changes in temperature by utilizing the effect of heat on the expansion of a liquid or gas, or on the change in voltage of an electric current.

Most thermometers used aboard ship are supplied with thermometer wells (separable sockets) into which their stems are inserted and tightened. A separable socket type of thermometer, inserted in the line or in the equipment where the temperature is to be measured, eliminates the necessity for closing down a system or securing a piece of machinery in order to remove a thermometer.

Usually, a thermometer well is first installed in an equipment or line. Next, the stem of the thermometer is coated with a heat conducting medium to increase the speed of response. A mixture of heavy mineral oil (vaseline, petrolatum,) and finely powdered amorphous graphite is used as the medium when the temperature to be read is not more than 300° F. If the temperature to be read is greater than 300° F, graphite alone is used as the heat conducting medium. Finally, the thermometer is inserted into the well.

LIQUID-IN-GLASS THERMOMETERS

Liquid-in-glass thermometers operate by the volumetric expansion of a liquid with temperature. If the temperature of a liquid is raised, the volume increases in relation to the temperature increase. When heat is applied to the thermometer bulb the expanding liquid is forced up a small bore column (called a capillary) in the stem to indicate temperature. Therefore, the liquid-in-glass thermometer is a direct reading instrument.

A reading is taken by observing the height of the liquid against a scale graduated in degrees of temperature. Graduations are either etched on the glass or etched or lithographed on a separate strip of material placed behind the glass. The latter style is the one used most by the Navy. The glass is divided into two main parts: a scale glass capillary tube and a glass bulb. It is also common to have an additional length of glass tubing as an extension stem between the scale glass and the glass bulb. The scale glass and scale are enclosed in an attached metal case with a plastic or safety-glass face. The stem and glass bulb are

enclosed in a metal tube or chamber. The filling liquid may be mercury or a non-toxic organic liquid colored red, black, or dark blue. (NOTE: Organic liquids such as ethyl ether, acetone, and toluene can be used so long as they are suitable for the range involved.) Ethyl alcohol, suited for measuring very low temperatures and having a lower freezing point than mercury, can also be used. At times, benzine may be used because it has a larger expansion rate than mercury; therefore, it would give a more accurate reading than mercury. Benzine also has a smaller span than mercury.

However, mercury is used extensively in liquid-in-glass thermometers because:

1. It has a high boiling point and a low freezing point.
2. Evaporation is negligible at the temperatures for which mercury is used.
3. If chemically pure, it does not adhere to the sides of the glass stem.
4. It expands and contracts with relatively small changes in temperature, which makes it quick and sensitive in action.
5. Its silver white color is easily discernible through glass, making reading easy.

CONSTRUCTION AND EXPANSION CHARACTERISTICS

The case enclosing the scale portion of the liquid-in-glass thermometer is made in the following forms, shown in figure 7-2:

1. Straight
2. 90° back angle
3. 90° right side angle
4. 90° left side angle
5. 45° reclined angle
6. 45° inclined angle

The metal tube or chamber enclosing the stem and glass bulb may be of the bare bulb type for direct immersion into the medium being measured or it may be made for insertion into a well or separable socket which, in turn, is immersed in the medium. The wells or separable sockets are made in the style shown in figure 7-3.

Navy type, 5-inch stem, mercury thermometers are used to take readings where space is limited, such as taking brine temperatures of ice machines, lubricating oil and bearing temperatures, water and fuel oil temperatures, and air compressor discharge air temperatures.

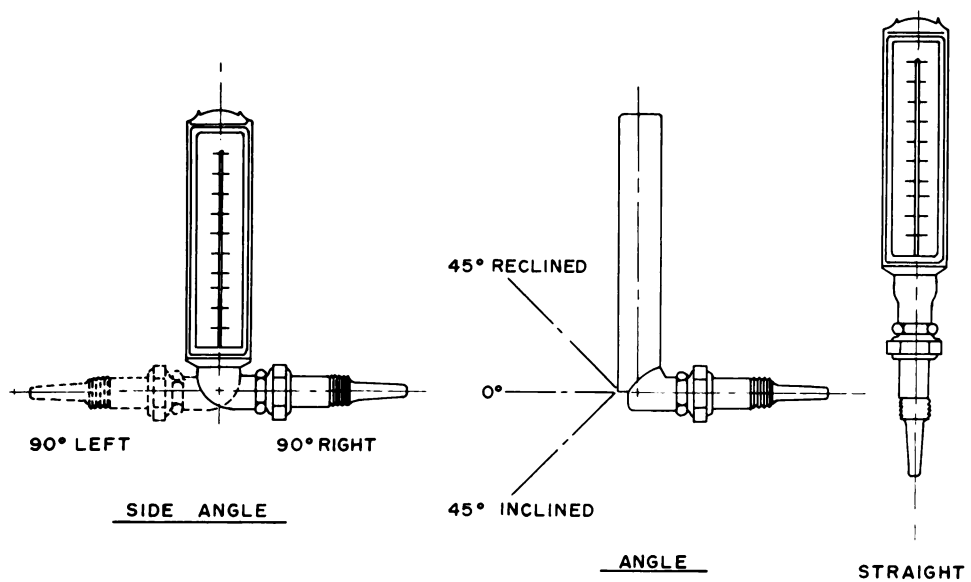


Figure 7-2.—Case forms for liquid-in-glass -thermometers.

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Industrial thermometers with 7-inch stems or 9-inch stems are used for all kinds of services. Because they have larger scales, they can be read more easily where light conditions are poor.

Mercury thermometers generally operate from -38.9°C (-38.0°F) to $\pm 400^{\circ}\text{C}$ ($\pm 752^{\circ}\text{F}$). The lower limit is the freezing point of mercury while the upper limit is a function of the thermometer glass. The upper temperature limit is restricted in that it must be well below the point where the thermometer glass starts to soften. Some special type thermometer glass may be safely used for temperatures as great as $+500^{\circ}\text{C}$.

The problem with organic liquids is that due to their physical characteristics, they tend to wet the capillary and, therefore, leave a thin film which causes errors. In addition, since they are clear, some coloration must be added so that the thermometer may be easily read.

There are also problems inherent with high temperature mercury-in-glass thermometers. As the temperature of the mercury rises, and it expands upward toward the end of the capillary, the pressure above the mercury increases. The pressure increases because as the mercury gets warmer its vapor pressure increases, and the volume of the gas above the mercury decreases. This increase in back pressure at higher temperatures causes the expansion of the mercury

to be nonlinear, or depressed, at higher temperatures. The effects of this increased pressure may be minimized by a two-fold operation.

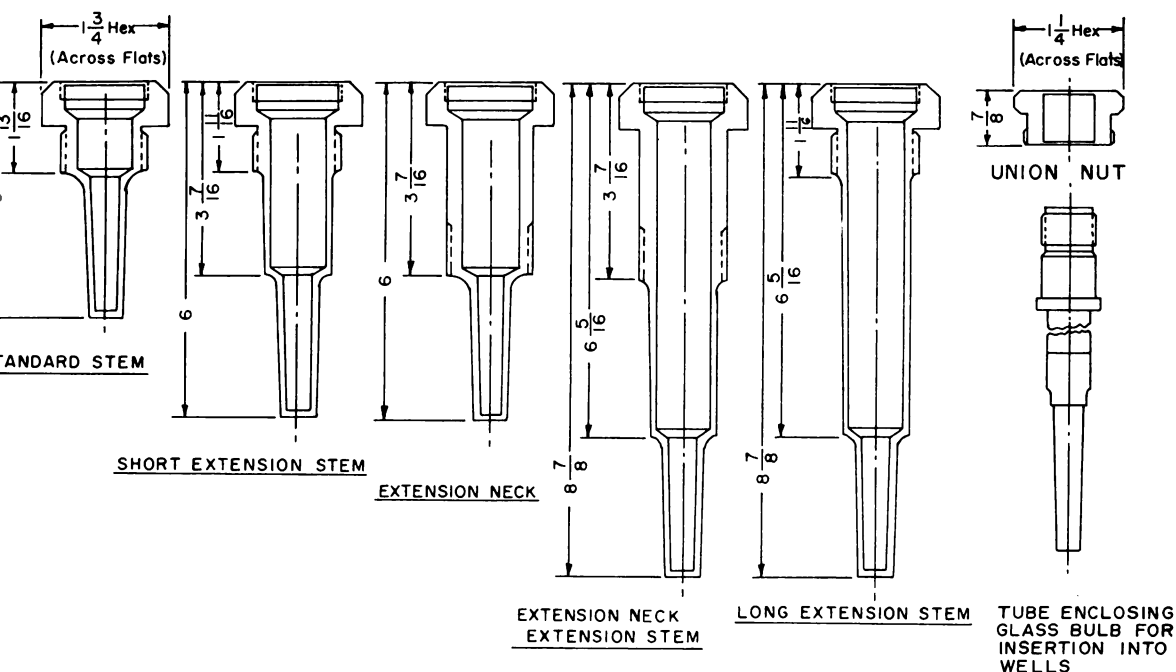
First, when the thermometer is manufactured, the space above the mercury is filled with an inert gas at a pressure equivalent to several atmospheres. Second, an expansion area is built into the top of the thermometer. The net effect of these two measures is that the pressure increase is minimized, and the effect of the pressure increase which occurs is of negligible proportion.

INSTALLATION

As mentioned previously, the metal tube enclosing the stem and glass bulb may be a bare bulb, installed directly in the medium being measured, or it may be made for insertion into a well or separable socket which is immersed.

When a liquid-in-glass thermometer is installed, however, consider the following factors:

1. Position the scale for maximum readability.
2. Ensure proper and adequate lighting at thermometer installations. If the thermometer is one which is not easily read, install an indicator to show at what angle it can be best read.
3. Select a location as free from vibration as possible.



61.150

Figure 7-3.—Well styles for 7 and 9 inch liquid-in-glass thermometers.

Never select a thermometer with a maximum graduation below the highest expected temperature.

Immerse the thermometer properly.

NOTE: As existing stocks are depleted all short scale length liquid-in-glass thermometers will be replaced with bimetallic thermometers, designed to fit into existing wells.

RATING PRINCIPLES

Thermometers with a scale range up to 750° F may be subjected continuously to any reading on the scale without injury to the instrument. Thermometers graduated up to 900° F, thermometers may be used occasionally with safety at the maximum temperature, but they should not be used continuously at temperatures above 850° F. Thermometers graduated up to 1,000° F may be used at the proper range limit, but their limit for continual use is 900° F.

When reading a thermometer, avoid parallax; keep the eye level with the top of the liquid column.

Allow sufficient time for the thermometer to reach equilibrium. Take several readings widely spaced over a period of time. Remember,

thermometers are slow in measuring gas temperatures, since gas has poor heat conductivity and low heat capacity.

Obtain adequate circulation. Thermometers immersed in stagnant gases or liquids will not give true average temperatures.

There are three basic types of liquid-in-glass thermometers commonly used; the partial immersion (fig. 7-4), the total immersion (fig. 7-5), and the complete immersion thermometers. (NOTE: The complete immersion thermometer is a rather specialized and obsolete instrument.)

Additional information concerning partial immersion, and partial and total immersion thermometers can be obtained from either Navy-Ships publications or the manufacturer's technical manual for specific equipment.

CARE AND MAINTENANCE

When handling liquid-in-glass thermometers, observe the following precautions:

1. Handle thermometers carefully, especially those of the etched scale type. They are easily broken.

2. Stow spare thermometers so that they will be free from shocks and jars.

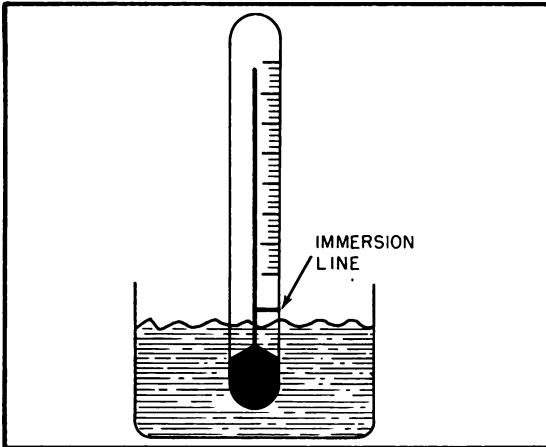


Figure 7-4.—Partial immersion thermometer.

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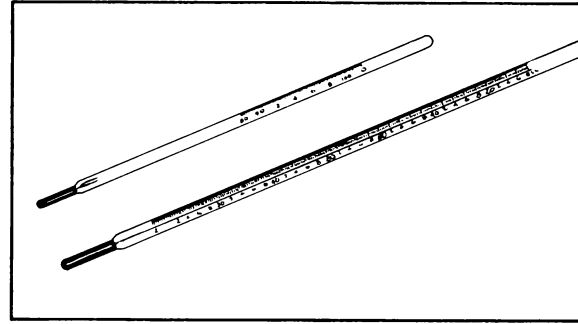


Figure 7-5.—Partial and total immersion thermometers.

61.

TESTING AND CALIBRATION

3. Thermometers located where they are exposed to damage during routine work should be removed and stowed while the ship is in port. When thermometer casings and sockets conform to Navy specifications, they are interchangeable, however, it is wise to mark each thermometer as to location so that a thermometer of proper scale range will always be re-installed in the correct socket. Always screw socket caps in place when thermometers are removed.

4. If the liquid column within the glass tube becomes broken or the liquid is separated, do not attempt to bring the parts together by tapping or jarring the thermometer. Hold the thermometer by the upper end and try to correct the trouble by several full-arm swings. If this does not succeed, try to rejoin the liquid thread by cooling the bulb to a sufficiently low temperature so that all the liquid is drawn into the bulb. If this is unsuccessful, carefully heat the bulb until the liquid threads join. If the separation enters the chamber, stop heating and allow to cool while tapping at the top. **OVERHEATING WILL BREAK THE THERMOMETER.**

5. Replace broken glass faces of liquid-in-glass thermometers promptly in order to protect the tube and to prevent corrosion of the graduated scale.

As far as adjustments are concerned, the scales are fastened to the case with four screws and the holes in the scale are elongated so as to permit adjustment of the two scale divisions.

The calibration test is made to determine condition and accuracy of the thermometer throughout its operating range. An initial calibration is made to establish the condition of the thermometer as received from the manufacturer or before being used or tested. Additional calibrations are made as required to determine the condition and any changes that may have occurred in the thermometer after it has been used or subjected to a test condition.

The calibration procedure must be performed in a liquid bath or baths, where one bath does not cover the entire range. Baths are designed in accordance with approved standards, such as MIL-STD- 735 (SHIPS). The master standard used should be reference standards, liquid-in-glass, mercury actuated, etched stem thermometers; reference or primary level thermocouples or resistance type elements. The master standard used should be of higher accuracy than the thermometer being calibrated and capable of giving results within 1/4 of the tolerance specified for the thermometer being tested.

The entire insertion length of the thermometer being tested must be immersed in a suitable stirred liquid bath. Readings should be taken at not less than five points spaced at nearly equal intervals over the operating range of the thermometer. At each point the bath temperature should be leveled out in such a manner as to eliminate lag between the thermometer and the master standard. A temperature rise or fall

one or two degrees in five minutes is satisfactory for the purpose.

As far as special calibration methods are concerned, let us consider the important facts concerning the remote reading filled systems, the filled system and bimetallic thermometers, and liquid-in-glass industrial thermometers.

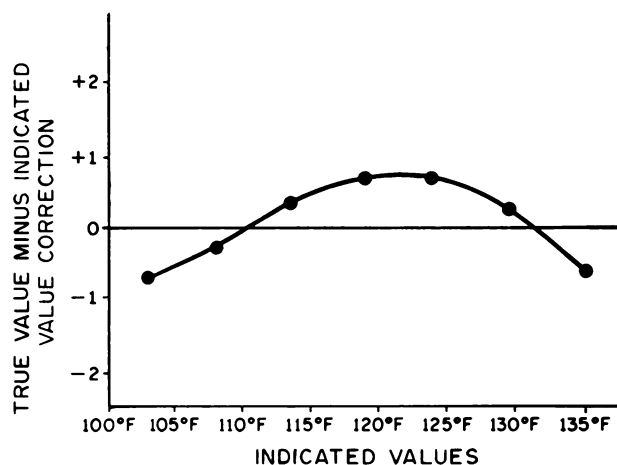
During the calibration test for remote reading filled systems, the indicator and capillary tubing should be at normal room temperature, approximately 75° F.

For filled system and bimetallic thermometers (discussed later in the chapter), the indicator shall be tapped near the center of the dial before each reading. If tapping causes a pointer shift greater than one subdivision, an additional test shall be made to determine the "dead band" of the thermometer, as follows:

Select a temperature within the middle third of the range and slowly bring the bath temperature to this value first from one direction, then the other direction. The dead band is the average difference between the thermometer readings at which the indicator comes to rest when the bath temperature, as indicated by the master standard, reaches the selected value from the opposite direction. The change in temperature for this test should not exceed plus or minus ten percent or be less than plus or minus five percent full scale value. (NOTE: The thermometer must not be tapped, jarred or vibrated during this test.)

The industrial type liquid-in-glass thermometers are in effect partial immersion thermometers. When used at any immersion other than that for calibrated, they will not give a true indication of bulb temperature. In general, the depth of immersion is fixed by the thread or the flange of the well. However, even when inserted to the proper depth, the bath differences in indication can still be caused by differences in heat transferred to or lost from the well, flange, or other parts of the thermometer not immersed in the bath liquid. Unless otherwise specified, the outer surface of the flange, where applicable, and those portions of the thermometer above the thread of flange shall be exposed to ambient (room) temperature (approximately 75° F) during the test. The case should be shielded from direct radiation from the bath liquid.

A typical calibration curve for the range of 100° F to 135° F (indicated values) is shown in figure 7-6. Drawn this way it is easily used and there is little possibility of error in its use. It should be noted, however, that the calibration



61.153

Figure 7-6.—Typical calibration curve.

curve obtained, as indicated, shows only the average amount by which the indication of the thermometer may be expected to vary from true temperature. (NOTE: For filled system and bimetallic thermometers the dead band is a supplementary measurement representing the amount by which the readings of the thermometer vary in successive indications of the same temperature.)

The following details are specified in the individual specification dealing with calibration.

All temperature measuring devices have a response time associated with them. This response time, a function of the instrument size, material, and temperature variation, might best be described as the amount of time required for an instrument to "catch up" with and indicate the measured temperature. Liquid-in-glass thermometers exhibit a response time in the form of a lag which is dependent upon the type of glass and the type of liquid. If 30 seconds are allowed for the thermometer to stabilize at a temperature in a liquid bath, the lag will cause an error of less than 0.0001° C. Longer stabilization times are required in air.

Additional information concerning a calibration report for a liquid-in-glass thermometer can be obtained from the manufacturer's technical manual for the specific equipment.

Precision total immersion thermometers are calibrated by comparing them against a platinum resistance thermometer or other similar liquid-in-glass instruments, which have been calibrated

against a platinum resistance thermometer. If a liquid-in-glass thermometer is calibrated by direct comparison against another liquid-in-glass thermometer, two standards are generally used to ensure a reliable calibration.

Thermometer calibration by comparison, other than fixed points, is generally carried out in a stirred bath similar to the simplified version in figure 7-7. Water is generally used as the bath media for temperatures up to 100° C. At temperatures up to 500° C, special oils with satisfactory viscosity characteristics and high flash points are used. The stirrer keeps the fluid in motion, thus minimizing thermal layers (hot spots) in the bath. The temperature sensor and controller work in combination to achieve and hold a constant temperature required for calibration. Figure 7-8 shows thermometer calibration baths or constant temperature baths generally found in a laboratory.

BIMETALLIC EXPANSION THERMOMETERS

All temperature measuring instruments utilize some change in a material to indicate temperature. One of the more important physical properties used in temperature measuring instruments is the change in length of a material in the form of expansion and contraction. If two metals with different linear expansion coefficients

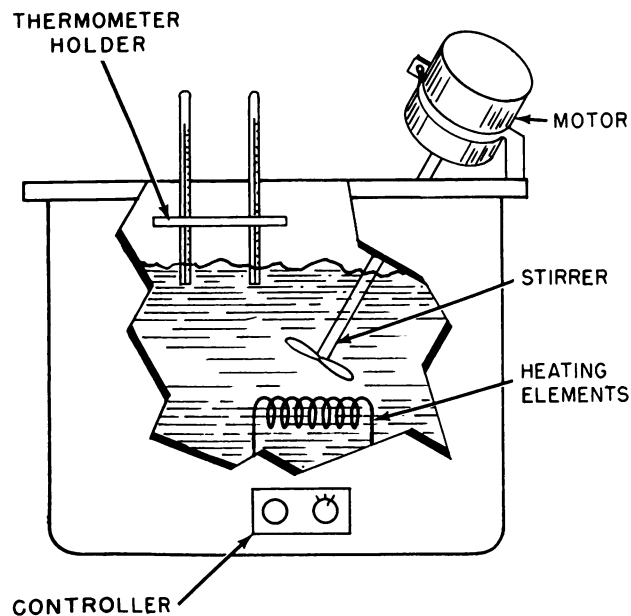


Figure 7-7.—Stirred bath.

are bonded together, as the temperature changes their rate of expansion will differ. This causes the entire assembly to bend in an arc. The arc will be formed around the metal with the smaller expansion coefficient. Since this assembly is formed by joining two dissimilar metals, it is known as a bimetal element. This simple device, when fixed rigidly at one end, finds numerous uses in temperature control circuits and electrical appliances.

A modification of this bimetal strip also serves as the basis for one of the simplest and most commonly encountered measuring instruments, the bimetallic thermometer shown in figure 7-9.

A bimetal strip is wound in the form of a long helix. One end of the helix is held rigid. As the temperature varies, the helix tries to wind or unwind, causing the free end to rotate. The free end is connected to a pointer which indicates the angular rotation of the helix. However, since the rotation is linear and a function of temperature, the scale is marked in units of temperature.

These instruments are relatively simple, rugged, and inexpensive; but, at best will only provide measurements with errors from $\pm 1^\circ$ F to $\pm 2.5^\circ$ F, depending upon the instrument range, size, and other factors.

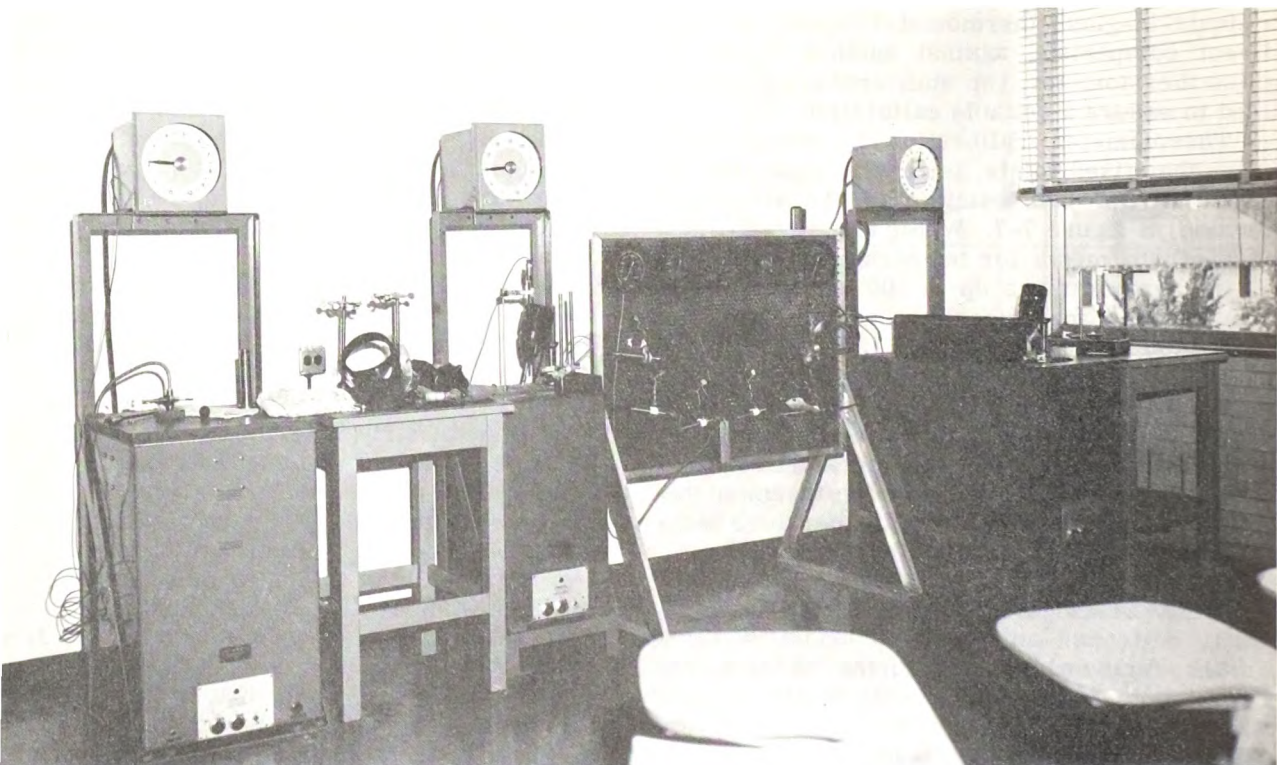
The bimetallic element is composed of two strips of metal fused together. Such metals as copper and Invar are used. (Each strip is made from a metal having a different coefficient of expansion.) This bimetallic element, when in the form of a spiral or helix, unwinds as it is heated and winds when cooled. The form of bimetallic thermometers used by the Navy is shown in figure 7-9. The pointer, attached to the upper end of the stem, indicates temperature over a circular dial as the strip winds or unwinds. A plastic faced case, enclosing the dial and indicating pointer, is welded to the protective tube. On all new bimetallic thermometers an external means is provided to adjust the instrument calibration by at least two subdivisions. A maximum or minimum index pointer and reset knob may also be provided.

INSTALLATION

When a bimetallic thermometer is installed, the following factors should be considered:

1. The thermometer may be installed with the protective tube either directly immersed in the fluid or inserted in a socket or well.

61.154



61.155

Figure 7-8.—Thermometer calibration baths or constant temperature baths.

2. Provide sufficient bulb immersion. In general, a minimum immersion of two inches in liquids and four inches in gases is recommended.

3. Locate the instrument in a place of minimum vibration from the equipment and minimum pulsation from the fluid.

4. Position the dial for easiest possible reading.

OPERATION

For maximum precision, tap the case lightly before taking a reading. In reading the dial, avoid parallax. Obtain adequate circulation of the fluid whose temperature is being measured.

CARE AND MAINTENANCE

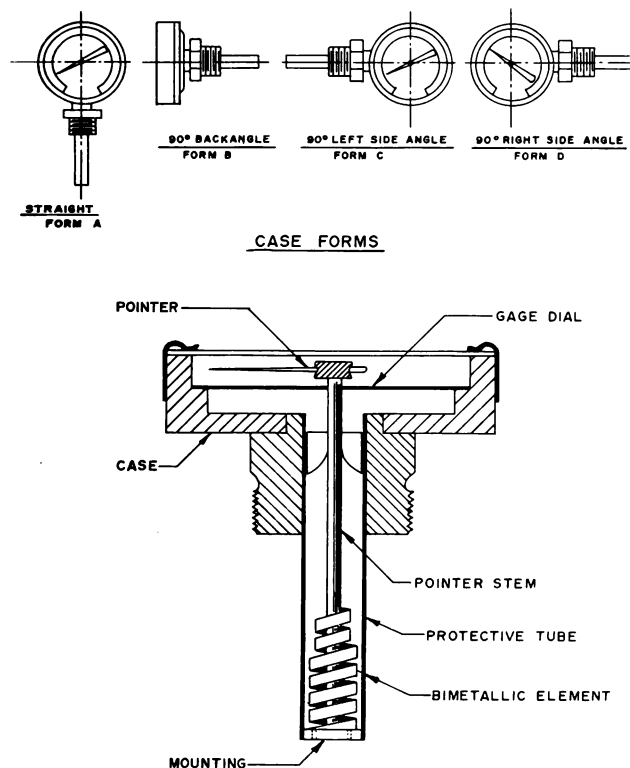
When handling bimetallic thermometers, avoid over temperature, shock or severe vibration. Any of these may distort the bimetallic

element and destroy the accuracy of the instrument. Damage to the bimetallic element from shock or vibration may not readily be apparent.

If the pointer does not move freely but jumps from point to point with changes in temperature, friction is present and probably due to a distorted element. A damaged bimetallic, or distorted, element cannot be repaired. A calibration adjustment is the only means of correcting the instrument.

FILLED SYSTEM, INDICATING THERMOMETERS

The construction and mechanical operation of all Navy type filled system thermometers is virtually identical. The filled system is an all metal assembly consisting of a bulb, capillary tubing, and a Bourdon tube. (The Bourdon tube consists of a closed and flattened tube formed into a spiral, helix, or arc which changes in shape when internal pressure is applied.)



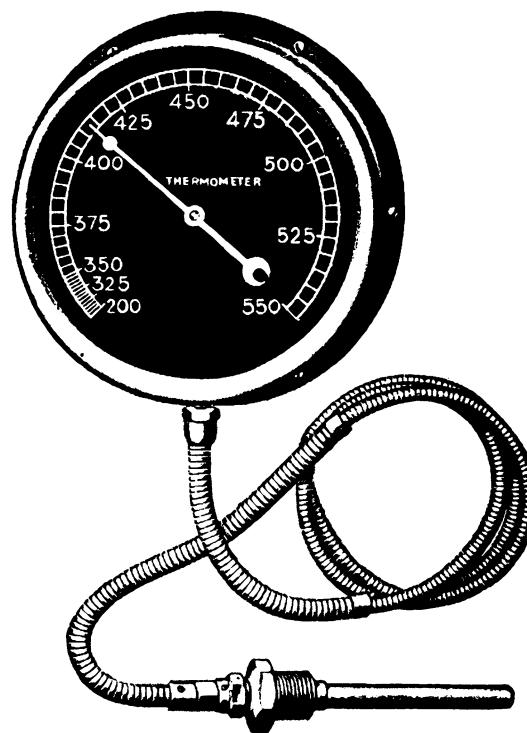
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Figure 7-9.—Bimetallic thermometer.

Distant reading dial thermometers (fig. 7-10) are used when indicating portions of the instrument must be placed at a distance from where the temperature is being measured. The distant reading filled system thermometer has a long capillary, up to 125 feet, which separates the sensing bulb from the Bourdon tube and dial. This allows remote reading of the temperature. (NOTE: The direct reading thermometer is very similar to the distant reading except that an extremely short capillary is used between the bulb and the Bourdon tube. In addition, the dial case is connected by a swivel joint to the end of the bulb assembly.)

TYPES OF PRESSURE SPRING THERMOMETERS

The three basic types of pressure spring thermometers are the liquid filled, the gas filled, and the combination liquid-vapor filled. The mercury filled, distant reading thermometer is the most common type used aboard ship.



61.28X

Figure 7-10.—Distant reading dial thermometer.

When the mercury in the bulb (of a mercury filled thermometer) expands, it transmits pressure through the capillary tubing to the Bourdon tube. When the Bourdon tube straightens out because of pressure in the line, it works a system of levers and gears which cause the gage pointer to move over the gage dial and register temperature or pressure, in accordance with the calibration of the gage scale. Expansion of mercury in the thermometer bulb communicates a pressure to the gage proportional to the temperature surrounding the bulb.

A gas actuated thermometer uses gas as the actuating element in the closed system. The gas most commonly used is nitrogen, though carbon dioxide and hydrogen are sometimes used for this purpose. A gas filled thermometer is similar in design to a mercury filled thermometer, but it has an advantage over the mercury filled type in that there is no restriction on the length of capillary tubing which can be used between the thermometer and the element being measured.

Some of the fluids used in vapor actuated thermometers are butane, ethyl alcohol, ethyl chloride, methyl chloride, propane, and sulphur dioxide.

The main advantage of a vapor filled thermometer is that longer lengths of capillary tubing can be used for measuring temperatures distant from the reading spot. The maximum line length recommended for a 3 1/2-inch thermometer is 50 feet.

A vapor actuated thermometer is not generally affected by ambient temperature (temperature of air, or other medium along the capillary line) because only the temperature at the free surface of the liquid affects vapor pressure in the system. (NOTE: In the vapor actuated system, the vapor does not expand uniformly so that the indicator scale divisions must be spaced wider apart at the high end.)

This is one advantage a vapor actuated thermometer has over mercury and gas actuated thermometers, which are affected somewhat by ambient temperature.

Study figure 7-11 which shows a vapor actuated thermometer. The arrows above the liquid in the bulb indicate the action of the vapor given off by the liquid. When the liquid is subjected to high temperatures, the amount of vapor pressure above the liquid increases. This pressure is transmitted through the capillary tubing to the registering element of the thermometer, where it is calibrated in degrees of temperature on the dial.

One disadvantage of a vapor actuated thermometer is that it is affected by head effect—the height of the thermometer bulb in relation to the registering portion. If the bulb is placed higher or lower than the position for which the dial is calibrated, there will be an error in reading.

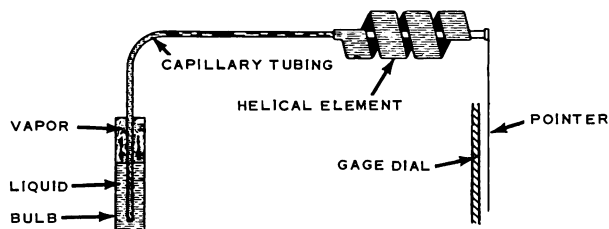


Figure 7-11.—Vapor pressure thermometer system.

This condition can be corrected by calibrating the dial in accordance with the position of the bulb.

All liquid filled and some gas filled thermometers require ambient temperature compensation. The common methods are:

1. Full compensation with an auxiliary system, less the bulb (figure 7-12) corrects for ambient temperature changes in the Bourdon tube and capillary by opposing erroneous response with an equivalent one of opposite sign.

2. Full compensation may also be accomplished by using case compensation plus a single precision drawn capillary enclosing a precision drawn Invar wire so that the expansion of the wire and mercury equals the expansion of the capillary (figure 7-13).

3. Case compensation whereby only the Bourdon tube, which is temperature compensated, is generally used in conjunction with minimum bore capillaries. Either a bimetallic strip or an opposing Bourdon tube is linked to counter the erroneous response of the receiving Bourdon tube (figure 7-14).

In most cases, however, the Bourdon motion is amplified by a mechanical linkage or gear system to drive a pointer for temperature indication. It may also be arranged to drive a pen for recording the temperature signal.

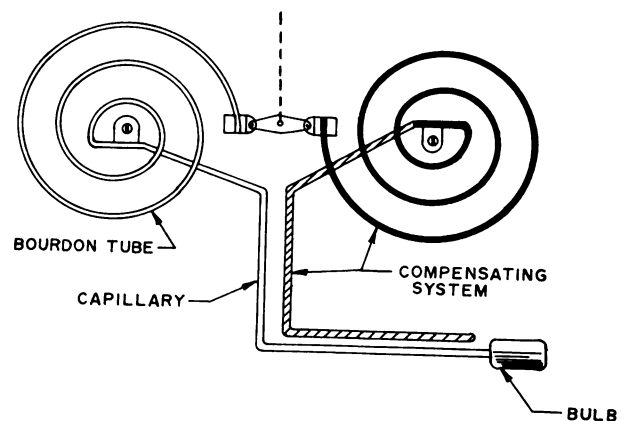
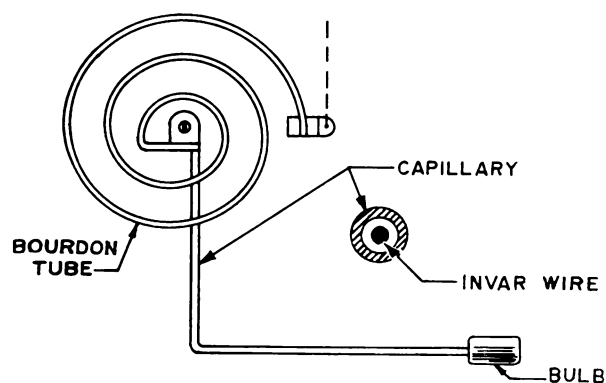


Figure 7-12.—Filled system full ambient temperature compensation with an auxiliary system.



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Figure 7-13.—Filled system full ambient temperature compensation with an Invar wire.

INSTALLATION

When filled system indicating dial thermometers (pressure spring thermometers) are to be installed, the following factors should be considered:

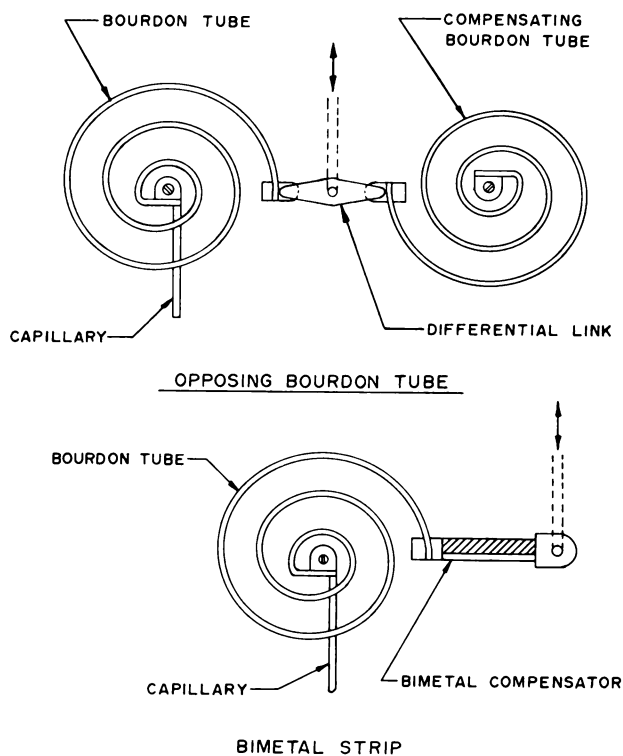
1. Bare bulb type thermometers, whether plain or flanged, are immersed directly in the medium whose temperature is to be measured. The flanged types are installed in appropriate flanged pipe branches.

2. Bulbs installed in protective wells are usually held in the well by a threaded union. To decrease the lag time, the space between the bulb and the well should be filled with heavy mineral oil and finely powdered amorphous graphite for maximum ranges below 400° F.

3. The filled system—Bourdon tube, capillary and bulb—is procured as a hermetically sealed unit and must remain as such throughout its service. Therefore, when these units are received for installation they must be unpacked and handled with extreme care. The capillary should be left coiled until it is to be installed. Avoid sharp bends or kinks where the capillary enters the gage and bulb. Do not handle or carry the unit with the gage or bulb suspended from the capillary.

4. When installing the filled system, be careful not to get any kinks or pinches in the capillary, and locate the capillary so that it will not be subsequently kinked or pinched. Any excess capillary should be coiled neatly.

5. Variations in temperature between the capillary and the indicator case may cause



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Figure 7-14.—Case compensation of filled systems.

slight errors. Install these so that the variation will be minimized.

6. The over-range capacity of most filled system thermometers is 100 percent, however, thermometers should always be selected with a range greater than the limits of the measured medium.

OPERATION AND MAINTENANCE

Readings are taken in the usual manner, as discussed earlier in the chapter, for pressure or temperature gages. Remember that parallax must be avoided. Any loss of liquid or gas can be repaired only by the manufacturer. Breaks in the capillary cannot be repaired aboard ship; the capillary cannot be spliced.

Bare bulb thermometers installed in pressurized systems such as superheated steam lines should never be removed for replacement or servicing while the system is operating under pressure.

Additional information concerning thermometers installed at the boiler superheat outlet location is given in chapter 9510 of NavShips Technical Manual.

TROUBLE DIAGNOSIS

Faulty operation of the indicator will be evident in the same manner as that of other Bourdon tube pressure gages. (See chapter 6 of this rate training manual.)

In steam line applications, if water appears behind the gage glass, it is likely that steam is leaking through the capillary. When steam is leaking through the capillary or from any portion of the bulb head or nearby armor, a failure of the bulb may have occurred and the thermometer should be replaced as soon as the boiler is secured.

PYROMETERS AND THERMOCOUPLES

The temperature of a body may be measured without any physical contact with it by using an instrument which senses radiation. Such an instrument is known as a radiation pyrometer shown in figure 7-15. The term pyrometer is used to include a number of temperature measuring devices which, in general, are suitable for use at relatively high temperatures; some pyrometers, however, are also suitable for use at low temperatures.

Pyrometers are used aboard ship to measure temperatures in heat treatment furnaces and exhaust temperatures of diesel engines.

The pyrometer consists of an indicator, usually a millivoltmeter or potentiometer, a sensing element consisting of a thermocouple, and electrical wires connecting the indicator and the sensing element. (NOTE: The potentiometer is not to be confused with the sliding resistor type device.) Thermocouples are composed of two dissimilar metals joined together at one end which produces a change in voltage proportional to a change in temperature at the joined end. A voltmeter (calibrated in degrees) indicates the temperature at the thermocouple.

The junction of a thermocouple placed at the point of measurement is called the hot junction (joined ends), which is usually welded. The other end of the thermocouple (usually within the measuring instrument) is called the cold junction. The hot junction may be placed as much as several hundred feet from the cold junction without affecting the accuracy of temperature

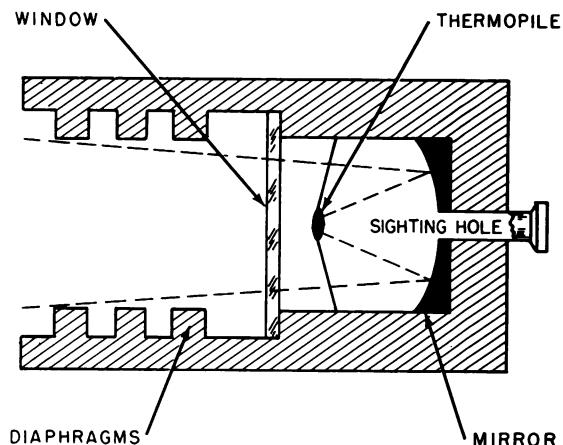


Figure 7-15.—Radiation pyrometer.

measurement. This feature of a thermocouple makes it excellent for measuring temperature in many locations aboard ship.

Types of metals or alloys used in combination in thermocouples are: (1) chromel-alumel, (2) copper-constantan, (3) iron-constantan, and (4) platinum-platinum rhodium. Other combinations may be used for special purposes.

CHARACTERISTICS AND APPLICATIONS

Because of the high cost of thermocouple wire, less expensive lead wire is often used to connect the thermocouple wires to the temperature indicating instrument. To minimize errors, it is desirable to obtain lead wires with the same thermoelectric characteristics as the thermocouple wire. For iron-constantan and copper-constantan thermocouples the lead wires are of the same material. For chromel-alumel thermocouples, however, copper and constantan lead wires are often used. For platinum-platinum rhodium thermocouples, copper and copper-nickel alloy lead wires are used. Lead wires, which are more rugged than thermocouple wires, may be solid or stranded.

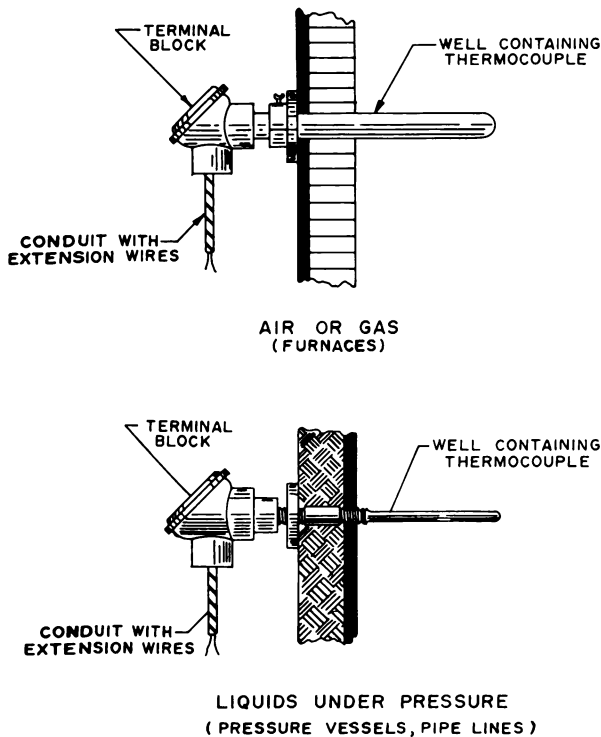
In only a limited number of applications it is practicable to expose the bare thermocouple to the fluid in which the temperature is being measured. Therefore, it is generally advisable to protect the thermocouple by means of a thermal well or a protecting tube. There are many types of thermal wells for thermocouples but those used by the Navy are classified as straight (rigid or union), angle, and special. In general, the

well is made in the form of a tube with a closed end, installed as shown in figure 7-16.

A millivoltmeter, installed in most naval applications, used with the thermocouple for temperature indication is shown in figure 7-17. As you know, the voltage generated by the thermocouple is measured in millivolts (1 millivolt = $\frac{1}{1000}$ volt). Since there is a definite relationship between the thermocouple voltage and the temperature difference between the hot and cold junctions, the scale of the meter is generally graduated in units of temperature.

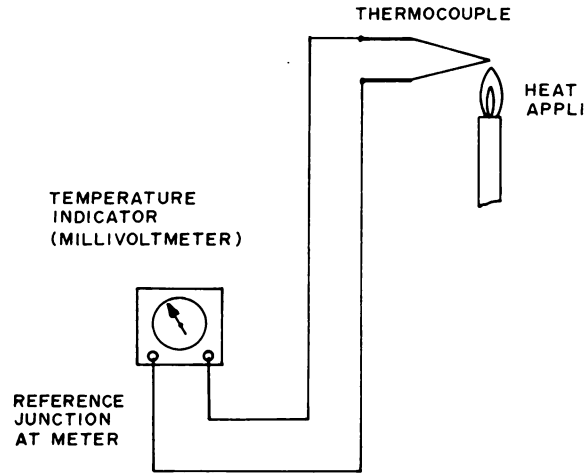
Compensation must be made for temperature changes at the meter because they affect the temperature of the reference junction located at the meter. This is generally accomplished by using a bimetallic strip in the meter coil spring mechanism.

Occasionally, there are applications requiring the use of a potentiometer circuit. This circuit consists of a battery, a standard cell, and a galvanometer. A simple circuit is shown in figure 7-18. Part of the battery voltage is compared with the thermocouple voltage. Any



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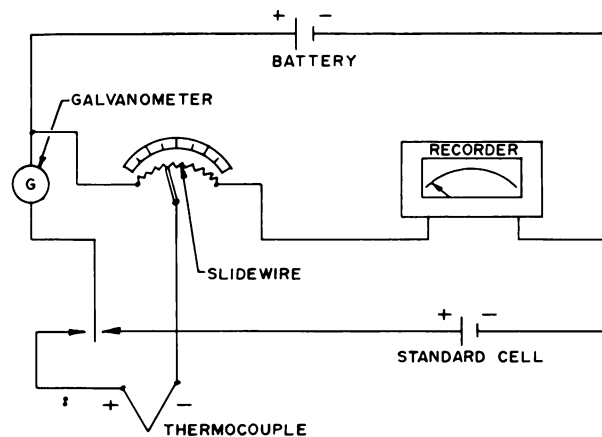
Figure 7-16.—Typical thermocouple installations.



61.16

Figure 7-17.—Thermocouple with millivoltmeter indicator.

difference in these voltages causes the galvanometer to deflect. The battery voltage is adjusted to a proper value by comparing it with a standard cell which has a fixed voltage. A sliding contact (or slider) moving along the slidewire can change the battery voltage to a value equal and opposite that of the thermocouple. This returns the galvanometer to its balanced position and no current flows through it. This condition is called null balance. The indicating pointer of the recorder is attached to the slider and its position is measured on a scale graduated in units of temperature.



61.16

Figure 7-18.—Standard potentiometer circuit.

Manual balancing is not satisfactory for most applications where the instrument must be in continuous balance for accurate recording or precise control. Various automatic systems are in use. In most modern type circuits, the galvanometer has been eliminated and replaced by a converter, an electronic amplifier, and a balancing motor.

Chromel-alumel and iron-constantin thermocouples are ones most frequently used by the Navy. Their characteristics are as follows:

<u>Material</u>	<u>Range</u>
Chromel-Alumel	600 to 2000° F
Chromel-Alumel	600 to 2300° F
Iron-Constantan	0 to 1100° F
Iron-Constantan	0 to 1400° F

Tables of temperature-voltage relationships for these thermocouples are readily available. The limits within which they conform to the tabulated values are: $\pm 5^\circ$ F for 0 to 540° F and $\pm 3/4$ percent of the reading from 541° F to maximum normal operating temperature of the thermocouple.

INSTALLATION

When thermocouples are to be installed, the following factors should be considered:

1. Select the thermocouple location to avoid stagnant areas of the measured fluid.
2. Avoid direct flame impingement on the thermocouple or protecting tube.
3. Select a protecting tube of adequate pressure rating for the system being measured.
4. Immerse the thermocouple into the medium whose temperature is to be measured sufficiently to minimize heat transfer along the protecting tube to the connecting head. A recommended minimum is approximately ten times the outside diameter of the protecting tube.
5. When measuring high temperatures, install the thermocouple in a vertical position to prevent sagging of the protecting tube.
6. The elements of the thermocouple must be electrically insulated from each other (except at the measuring junction), from ground and from conductors on which they may be mounted.
7. Extension wire (lead wire) installation requires that you observe the following factors:
 - a. Use only the proper type of extension wire for a given type of thermocouple.

b. Select the proper insulation to meet the installation conditions.

c. Observe the polarity of the individual connectors—connect the negative lead to the terminal at both the thermocouple connection head and the indicating instrument.

d. Avoid splicing the wire. If it is necessary to splice, solder and tape to avoid shorting or grounding at the splice.

e. Install extension wires in conduit whenever possible, and ground the conduit to prevent leakage from the power of the lighting circuits.

f. Do not run wires parallel to or across any 115 volt or higher alternating current within a distance of one foot. Induced alternating current may affect the pyrometer readings. Never run electrical wires in the same conduit with thermocouple extension wire.

g. For some installations, the thermocouple junction may be embedded directly in a piece of machinery. In this case, installation methods will be determined by the special characteristics of the machinery.

OPERATION AND MAINTENANCE

Millivoltmeters and potentiometers are delicate instruments which should be handled with extreme care. These instruments can be read in the same manner as other indicators or meters. Thermocouples should be checked regularly (once each month is considered sufficient). If possible, check thermocouples in place. If it is necessary to remove the thermocouple, return it to the same insertion depth, or deeper, because of errors arising from inhomogeneity of the heated portion of the wires. It should be noted that one of the prime requisites for a thermocouple to meet tolerance is that it must be homogeneous. When thermocouples are handled they are bent and/or contaminated unless extreme care is exercised by the user. Both bending and contamination cause the thermocouple to be nonhomogeneous, thereby affecting its operation and limit of error. There are strong arguments that used thermocouples should not be recalibrated as it may be more economical to replace them with new ones.

Burned out protection tubes should be replaced immediately to avoid damage to thermocouples. To check out extension wire circuits, remove the indicator and thermocouple connections and use a magneto set or megger to test insulation resistance. If instruments are

connected in parallel from the same thermocouple, check carefully for the effects of one instrument on the other.

RESISTANCE THERMOMETERS

The resistance thermometer consists basically of a sensing element, a resistance measuring instrument, and electrical conductors connecting the element and instrument. The sensing element is a fine wire wrapped around an insulator and enclosed in a metal bulb. The wire may be platinum, nickel or copper made to have a fixed resistance at a given temperature. Bulbs are made in various forms such as straight-rigid, straight-union, and angle. The outer end of the bulb is fitted with a watertight terminal head.

Since temperature measurement by resistance thermometers is actually a resistance measurement, the indicator used is basically a d-c Wheatstone bridge with variations. (NOTE: In a Wheatstone bridge, four resistance arms form a closed circuit. One resistor is variable, two have fixed values, and the remaining one, the sensing element is unknown.) The simplest form of resistance thermometer which uses an indicating millivoltmeter with the Wheatstone bridge is shown in figure 7-19. As the temperature of the sensing element rises, its resistance rises causing the bridge to become unbalanced. This is detected by the millivoltmeter which deflects to give an indication of the temperature on an appropriate scale. The resistance bulb has three leads so that the same amount of lead wire is used in both branches of the bridge. This compensates for variable lead-wire resistance.

RANGE, SERVICE, AND ACCURACY

The basic operating temperature range of the platinum resistance thermometer is -183°C to $+500^{\circ}\text{C}$. The upper usable temperature is limited by the softening point of the glass enclosure. The range may be extended to 650°C if the glass tube is replaced by one made of quartz.

Although thermometers of copper, nickel, and oxides are not as accurate, they are used to a great advantage, particularly in industry. Thermometers made of these materials are very similar to the platinum device except that they

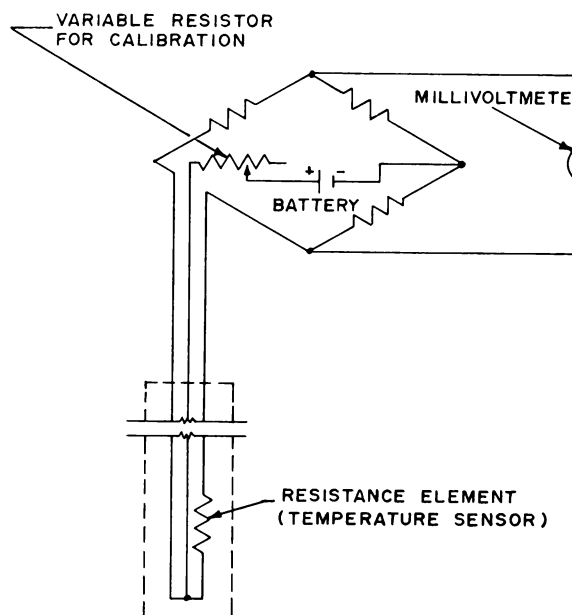


Figure 7-19.—Resistance thermometer using Wheatstone bridge circuit with a simple indicating millivoltmeter.

are generally less expensive and cover a more restrictive temperature range.

INSTALLATION

The following factors should be considered when installing resistance thermometers:

1. When the sensing element is to be installed in a threaded or flanged protecting tube, information given earlier in the chapter for installation of thermocouples is applicable. When the sensing element is embedded directly in a piece of machinery, installation is unique to the conditions present.
2. Make each lead wire from the sensing element of exactly the same length and of the same diameter wire so that their total resistance is the same. The wires should be run in the same cable through as uniform temperature conditions as possible. As large a size of copper wire should be used as practicable in order to obtain a low total resistance.
3. Where variations in line voltage of more than ten percent are present, a constant voltage

transformer of adequate power capacity should be used.

OPERATION AND MAINTENANCE

In general, the information covered for the operation and maintenance of thermocouples, mentioned earlier in the chapter, is applicable to resistance thermometers.

However, one word of caution concerning platinum resistance thermometers is that when these instruments are used to measure the resistance of the element, some current must flow through the element. The current produces self-heating of the element which may result in an erroneous temperature indication. To preclude this problem, all platinum resistance thermometers are calibrated with a specific current flowing through them (generally about 2 ma). If some other current is used during calibration, it will generally be noted on the calibration report. When using platinum resistance thermometers, extreme care should be taken to ensure that the thermometer is used with the same current as specified at calibration.

In addition, all points discussed for the operation and maintenance of thermocouples may be applied to resistance thermometers.

THERMOMETER TEST EQUIPMENT

The temperature room aboard a typical repair ship is designed for calibrating thermometers between -50°F and 1000°F . Liquid-in-glass, bimetallic, and distant reading type thermometers, which are most common aboard ship, can be calibrated in the temperature room. Figure 7-20 shows the high, medium, and low range temperature baths from left to right and their respective indicators; these comprise the primary equipment for the calibration of thermometers. The information which follows supplements that given earlier in the chapter.

DESCRIPTION

The bath units provide the calibration temperatures by heating or cooling the bath media as appropriate. A molten salt is used in the high temperature bath while certain silicon liquids are employed in the medium and low temperature baths. The instruments shown in figure 7-20 act as masters for indicating the bath temperatures.

Two of the master indicators of figure 7-20 and their respective temperature resistance elements are shown in figure 7-21. These elements are immersed in the bath liquids during a thermometer calibration. Shipboard resistance thermometers and associated indicators can also be calibrated using the temperature baths shown in figure 7-20 together with the portable electrical resistance bridge and resistance box shown in figure 7-22. Thermocouple measurement equipment is shown in figure 7-23.

OPERATING PRINCIPLES AND PROCEDURES

The information which follows serves to describe the units of temperature baths as well as the operating principles of the equipment. As an IM3 or an IM2, you will be working with high, medium, and low constant temperature baths. It will be your responsibility to operate the calibration baths, check the operation of the baths at different temperatures, and verify the ability of controllers to hold the baths at constant temperatures.

High Constant Temperature Bath

The high constant temperature bath is designed to calibrate thermometers, filled system temperature instruments, and other temperature indicating devices. The bath, whose operating range is from 400°F to 850°F , consists of the heated tank assembly, the stirrer, and the temperature controller.

The tank assembly consists of an inner tank, which is composed of extra heavy cast iron, and has no fittings or seams because of the large amount of expansion. Heat is supplied by electrical strip heaters attached to the outside wall of the inner tank. The quick heating push button is designed to bring the bath up to the desired temperature rapidly. (NOTE: The push button can only be energized when the control heat is On. It automatically cuts out at about 10°F from the desired temperature. DO NOT HOLD THE BUTTON "ON" FOR ANY LENGTH OF TIME.)

The auxiliary heat selector is used to supplement the desired temperature. A switch (five position) controls the amount of heat supplied by the heater. (NOTE: Loss of heat is prevented by means of insulation.)

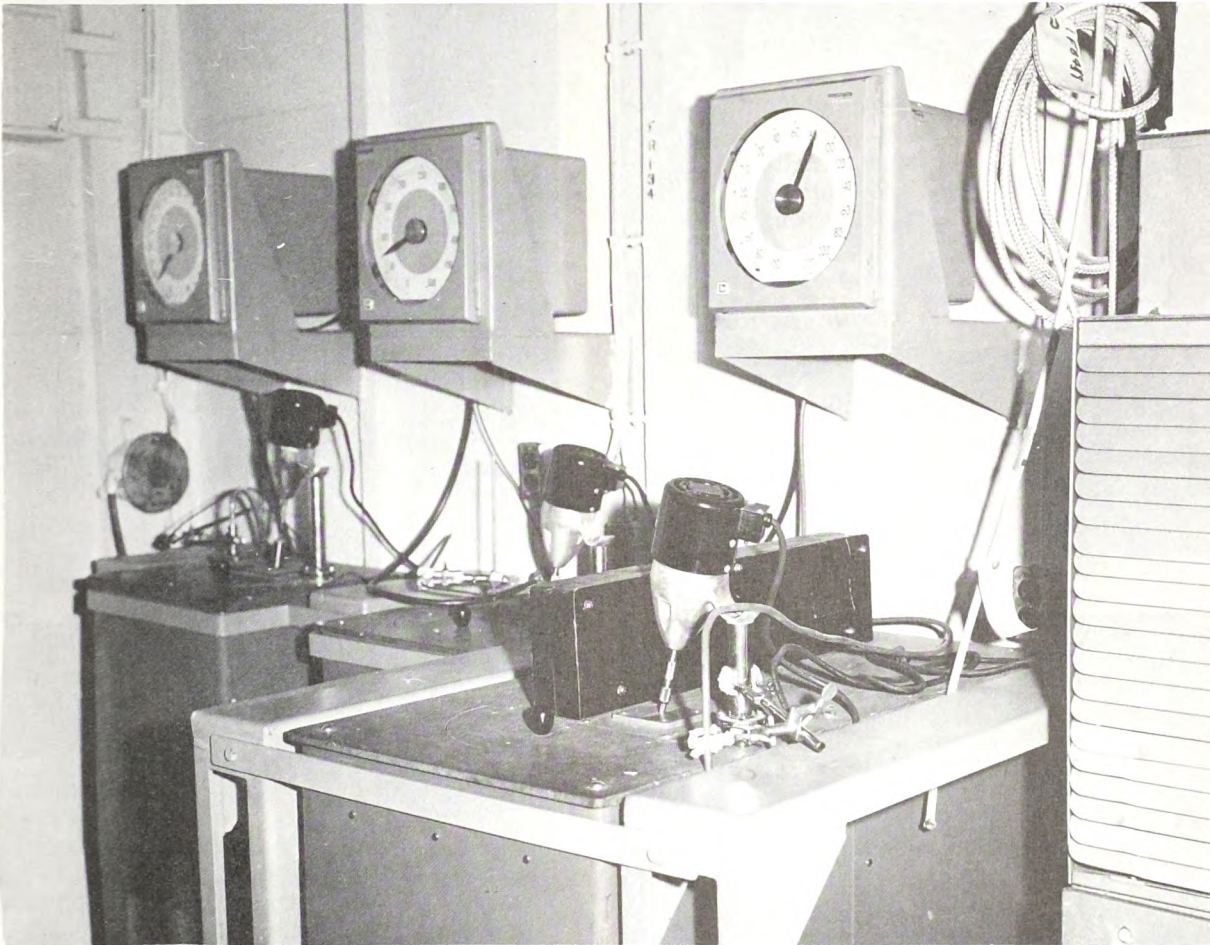


Figure 7-20.—Thermometer calibration equipment (temperature room).

The bath medium is a water soluble heat treating salt, which melts at 375°F approximately, transfers heat energy from the heaters to the test instrument sensing element. (CAUTION: When heated to 1300°F , a toxic gas is produced. Do not leave the bath unattended.)

The stirrer, which provides agitation of the bath medium and reduces thermal layers, should be lubricated every two months.

The temperature controller consists of a control panel which has a power ON-OFF switch and course and fine dial adjustments. By means of the control panel equipment, the strip heaters are energized and the desirable bath operating temperature is maintained. The pilot light indicates that the control heater is operating.

Before operating the temperature bath, the following initial conditions must be satisfied:

1. All power is secured
2. Stirrer unplugged
3. Tank cover in place
4. Fine dial adjustment set at 500
5. Course dial set to equal the desired temperature

a. Approximate settings are plotted on graph (found in manufacturer's technical manual)

b. Ambient temperature, amount of medium, and number of bulbs in the bath affect these settings

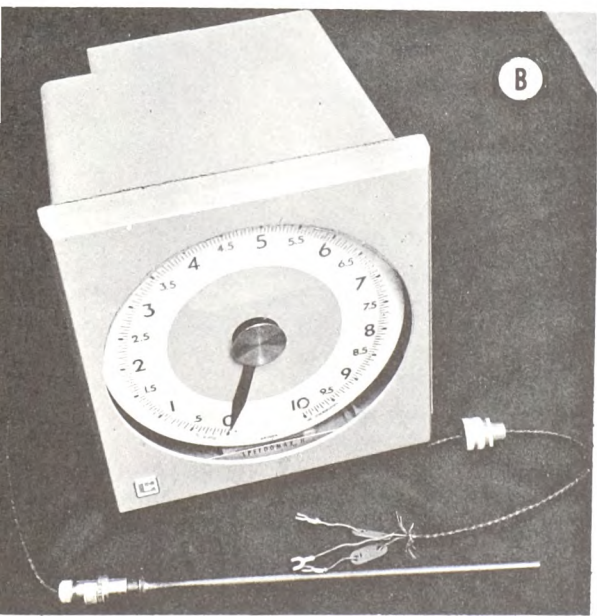
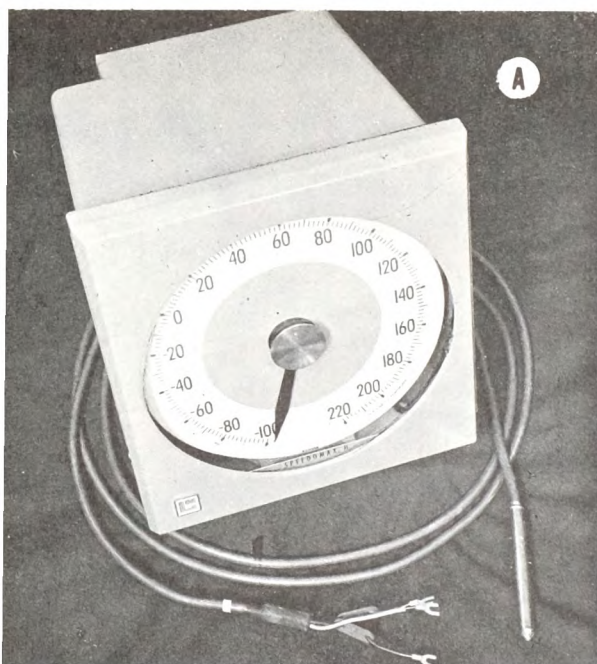
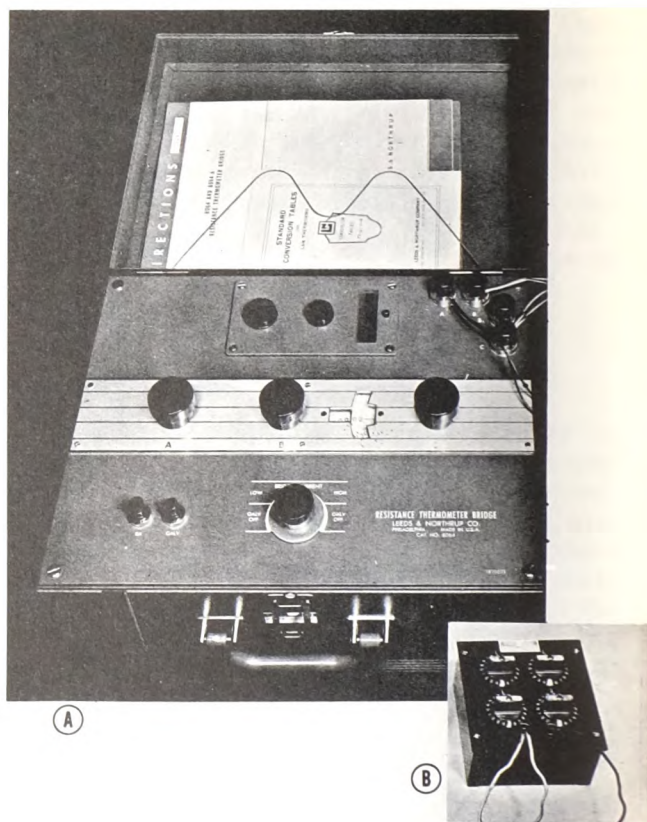


Figure 7-21.—Thermometer bath standards. (A) Copper resistance thermometer and master indicator; (B) Platinum resistance thermometer and master indicator.

To operate the bath, proceed as follows:

1. Turn power switch ON.



61.167
Figure 7-22.—Resistance thermometer equipment. (A) Resistance thermometer bridge; (B) Resistance box.

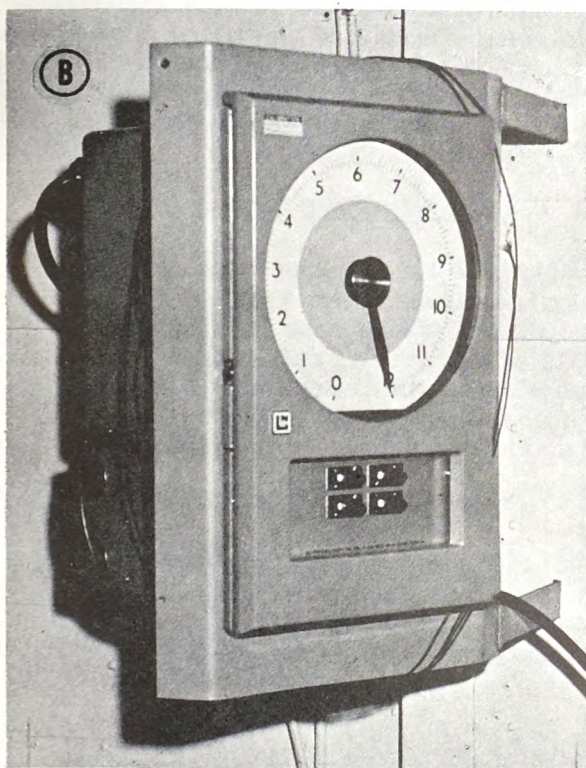
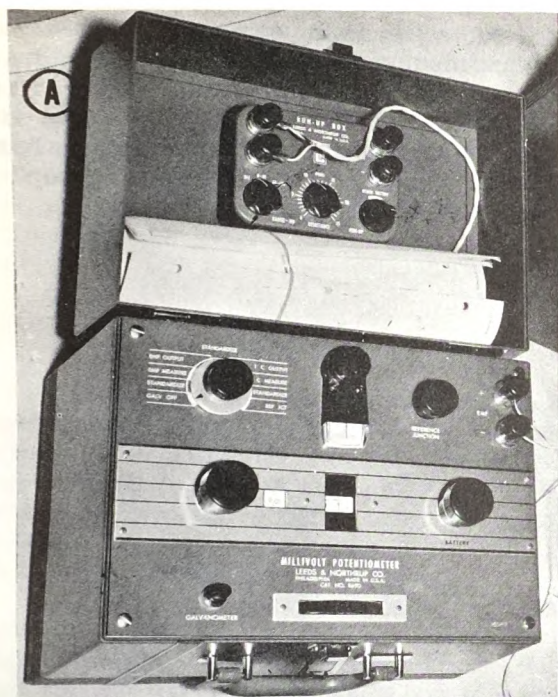
2. When the pilot light comes on, push the quick heat button.

3. Set the auxiliary heat to high. When initially lighting off this bath, add as much auxiliary heat as possible. The salt will melt within two hours approximately. The auxiliary heat should be turned OFF within 10° to 20° of the desired temperature.

4. Turn stirrer on. Check the rotation of the impeller by hand before starting. Be prepared to secure if there are lumps of unmelted salt.

5. Place the sensing element from the working standard in the bath. The following precautions should be observed:

- a. Wear face shield, gloves, and an apron when working with this bath.
- b. Always secure the stirrer when placing thermometer bulbs in the bath.



61.168
Figure 7-23.—Thermocouple measurement equipment. (A) Millivolt potentiometer; (B) Thermocouple multipoint indicator.

c. See that the bulbs are clear and dry.
d. Any water in the bath may cause a violent reaction.

e. Keep thermometer bulbs away from the side of the bath, the impellers, and the immersion heating or cooling coils, if any.

6. Allow the bath to stabilize.

7. When the pilot light starts blinking at regular intervals, adjust the auxiliary heat, if necessary, until you have a 50 percent duty cycle.

8. Allow the bath to stabilize.

9. Adjust the dial, in accordance with heat requirements (additional or less), to bring the bath up to the desired temperature.

10. When securing the bath, always remove the sensing element from the working standard.

Medium Constant Temperature Bath

The range for the medium constant temperature bath is from ambient to 450° F. The tank assembly consists of a stainless steel inner tank, and drain, and overflow connections. The medium constant temperature bath is also equipped with quick heat push button strap heaters. Auxiliary heat is not required because of the range. To control heat, an immersion heater is located in the inner tank.

No cooling equipment is hooked up. Cooling is provided, however, by a coil of stainless steel tubing (located in the inner tank) through which water is run; this may be used to lower the bath temperature rapidly.

The bath medium is silicone oil (Dow Corning 510) whose flash point is 525° F. The temperature controller is the same as that for a high constant temperature bath.

Low Constant Temperature Bath

The range for the low constant temperature bath is from -40° F to 200° F. The inner tank of the tank assembly is the same as that for the medium constant temperature bath. No quick heat push button equipment is required. Strip heaters are used as auxiliary heaters, when required. The heat control equipment is the same as that for the medium constant temperature bath.

Cooling is provided by a refrigeration unit. The cooling coil is located in the inner tank. When the refrigeration unit is on (cool position heat/cool switch), there is no control over the

amount of cooling. Heat input into the bath during constant cooling of the refrigeration unit controls the bath temperature. (NOTE: The oil level in the compressor must be checked periodically.)

The bath medium is silicone oil (Dow corning 200) whose flash point is 450° F. The tem-

perature controller is the same as that used for the high and medium constant temperature baths.

As far as the temperature calibration procedure is concerned, it should be performed in accordance with manufacturer's instructions for the specific equipment, or NavShips recommendations, where applicable.

C H A P T E R 8

TACHOMETERS

A tachometer is an instrument used to indicate rotary speed of a shaft in revolutions per minute (rpm) and surface speed of a shaft in feet per minute (fpm). For example, you can determine the revolutions per minute of a motor by holding a portable tachometer against the shaft of the motor while it is running.

Before you can advance to Instrumentman 3, you must be able to test the calibration of a mounted-type, continuous-indicating tachometer; and you must also know how to overhaul and calibrate mounted and portable, continuous-indicating tachometers. This chapter, therefore, provides information on the types of tachometers you will repair in the instrument shop, or MIRCS, with particular emphasis on overhauling and calibrating.

CENTRIFUGAL TACHOMETERS

Centrifugal tachometers used in the Navy are of two types: (1) portable, single- and multiple-range; and (2) permanently mounted or fixed, single range; also referred to as CONTINUOUS DUTY. Each type is discussed in some detail in the sections which follow. The centrifugal tachometer is used on any accessible shaft.

FIXED CENTRIFUGAL TACHOMETERS

Fixed centrifugal tachometers (fig. 8-1) made in accordance with Navy specifications are shockproof and vibration-proof and have suitable splashproof metal cases designed for panel or bulkhead mounting.

Operating Principles

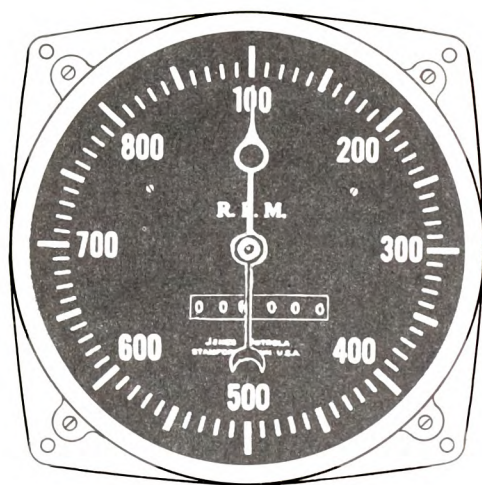
In order to properly maintain, overhaul, and calibrate all types of centrifugal tachometers, you must first understand the principles of operation of these tachometers. In this instru-

ment a centrifugal, flyball type governor is employed to convert rotary motion into angular displacement.

The governor mechanism, shown in figure 8-2, consists of three weights, each hinged at the center between two links. The links, in turn, are hinged to the upper and lower spiders. The lower spider, connected to the disk, is free to slide on the spindle shaft. When a given speed is applied to the drive shaft, the centrifugal force acting on the weights overcomes the resistance of the governor spring. This causes the weights to fly out, raising the disk until the two forces are again equal. The vertical position of the disk therefore, is determined by the applied speed.

The upper surface of the disk's lower flange is highly finished to provide a riding surface for the indicating mechanism's shoe. The shoe is pinned at the end of the calibrating lever, which is fixed to the shaft of the sector assembly (usually between the pinion assembly and the calibrating screw). The parts of a calibrating lever assembly are shown in figure 8-3.

The calibrating screw has a flange next to its head. This flange fits in a slot in the head of the moveable member. The calibrating screw moves the moveable member of the calibrating lever to which the shoe is pinned. Hence, when you turn the calibrating screw in a clockwise direction, the shoe moves toward the upper surface of the lower flange of the governor disk; and when you turn the calibrating screw in the other direction, the shoe moves away from the flange of the governor disk. The calibrating lever is secured to the sector assembly staff and causes it to rotate. The sector meshes with the pinion assembly and rotates it. Because the pointer is friction fitted to the pinion staff, it is also rotated, indicating rpm or fpm on the dial. Any change in the speed of the tachometer shaft is immediately transferred to the pointer.



61.18X

Figure 8-1.—Mounted-type centrifugal tachometer.

Installation and Maintenance

The fixed-type centrifugal tachometer, shown in figure 8-1, has an odometer (counting) mechanism to record the number of revolutions made by a moving shaft.

A diagram of the front part of the case, part of the flexible shaft, a right-angle drive unit, and the depth of the case (with flexible shaft connection) is shown in figure 8-4. To prevent wear, an unsteady pointer, and breakage, a right-angle drive unit is essential when there is an unavoidable bend of less than 12 inches in radius in the flexible drive shaft. This drive shaft may not exceed 25 feet in length.

The flexible drive shaft is connected from the tachometer to a takeoff gear on the piece of operating machinery, adjacent to the FIXED tachometer. The takeoff gear secures the flexible shaft to the shaft whose speed is to be measured.

The following conditions should be checked:

1. The drive outlet—for play and eccentricity. Either condition can cause an unsteady pointer or breakage of the flexible shaft or right-angle section drive (if used at the drive end).
2. Right-angle drive section (at lower or drive end)—for smoothness of operation. If sticking or jamming is indicated, replace the section.

3. After disconnecting the lower end of the flexible shaft from the drive or right-angle section, turn the flexible shaft by hand to check freedom of operation. If stickiness or a bind is indicated, disconnect the shaft from the top or tachometer end and check the shaft separately. If binding is evident, remove the flexible shaft from its outside cable and check it for wear and lack of lubrication. If lubrication is required, use a very light coat of Vaseline or similar light grease. If there is evidence of wear, especially close to either end of the shaft, replace the shaft and eliminate bends at ends.
4. With the flexible shaft in normal operating position, check it for sharp bends (one made on a radius of less than 12 inches). If a shaft is too long, it should be cut down or replaced with one of correct length.
5. Check the tachometer for smoothness of operation. Turn it by hand with a tool which fits over the square drive shaft. First, turn it slowly in both directions; then spin it in both directions and observe action of the pointer. If trouble is evident in the tachometer, disconnect it and take it to the instrument shop for further analysis.

Accuracy of Fixed Centrifugal Tachometers

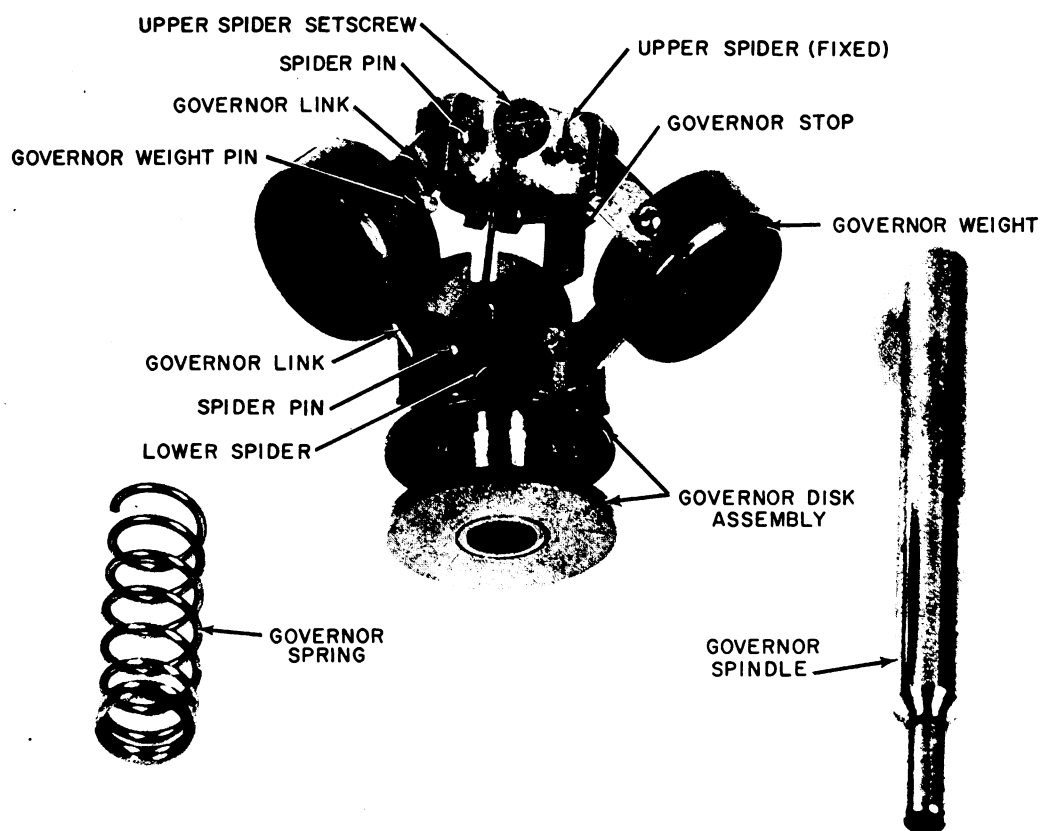
The allowable error for fixed centrifugal tachometers may not be greater than 2 percent of the full scale reading for any ambient temperature over the range of 40° F to 130° F for any position of operation within 45 degrees of the normal operating position.

Casualty Analysis and Repair

In order to restore an inoperative tachometer to working condition, you must be able to determine what is and what is not functioning properly. This process is known as casualty analysis. Casualty analysis is performed (1) before, during, and after disassembly, (2) during cleaning, (3) before, during, and after reassembly, and (4) during calibration.

In other words, casualty analysis is visually and mechanically inspecting all parts for evidence of wear, binding, and broken parts.

GOVERNOR.—When examining the governor, check the smoothness of the disk sliding on the



61.23

Figure 8-2.—Governor assembly of a centrifugal tachometer.

spindle by slowly and carefully compressing the governor and then releasing it. Be sure that when compressing the spring, no pressure is brought to bear on the lower flange of the disk. Since the calibrating lever shoe rides on the lower flange, if it was bent, it would cause pointer fluctuation. Apply even pressure on the opposite sides of the upper flange to prevent cocking.

If the governor sticks, scrapes, feels sluggish or rough, or the spindle is coated with a dull film, clean or replace, as necessary, the governor assembly.

Replace the governor assembly if any of the following conditions exist:

1. Bent or severely worn links.
2. Missing or broken pins.
3. Disk worn, bent, or gouged.
4. Spindle ends bearing surfaces worn or scored.

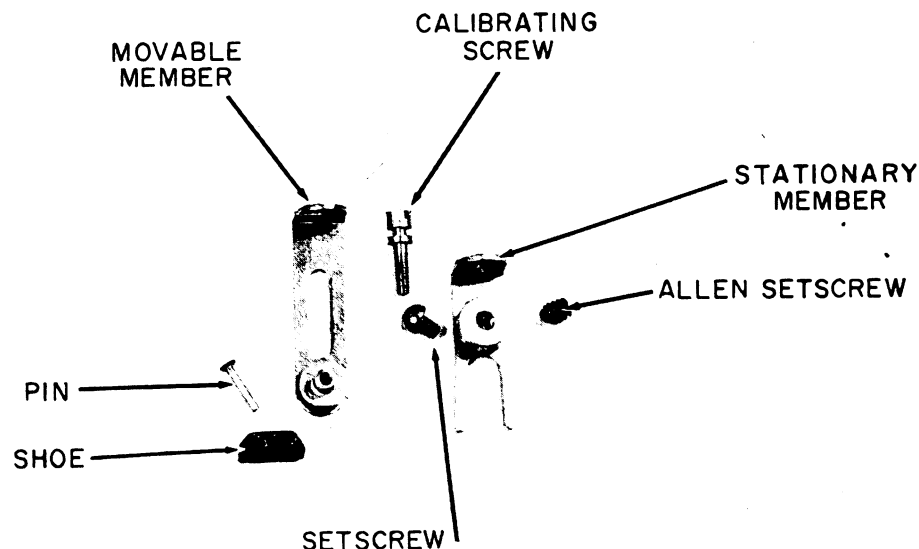
5. Spindle shaft worn or scored.
6. Spiders cracked or threads stripped.
7. Weak set, deformed, or broken governor spring.

DRIVE SHAFT ASSEMBLY.—Examine the gear teeth of the drive shaft assembly for signs of excessive wear, gouging, or roughness. Hold the assembly at the drive end and spin the outer bearing race. There should be a minimal amount of axial movement between the outer race and the drive shaft.

If the drive assembly does not spin freely, feels rough, or has excessive end play, clean or replace as necessary.

The drive shaft assembly should be replaced if any of the following conditions are observed:

1. Drive tip rounded, worn, or distorted.
2. Damaged or rusted ball bearings.



61.25X

Figure 8-3.—Parts of a calibrating lever assembly.

3. Bearing sleeve damaged or worn.
4. No play between the teeth of the drive shaft gear and the governor spindle gear.
5. Excessive wear of the drive shaft gear.

MOVEMENT ASSEMBLIES.—Slowly rotate the calibrating lever through its arc by applying pressure at the shoe end. The lever should pivot smoothly and without binding.

If binding or roughness is noted, clean the assembly. If the mesh still feels rough after cleaning, replace the assembly.

The movement assembly of the centrifugal tachometer should be replaced if any of the following conditions exist:

1. Pinion or sector gear teeth severely worn or broken.
2. No play between the teeth of the sector and the pinion.
3. Pinion shaft bent, worn, or broken.
4. Sector loose on its shaft.
5. Hairspring broken, weak, or badly distorted.
6. The movement plate or bridge bearing holes worn or elongated.

CALIBRATING LEVER.—When examining the calibrating lever of a centrifugal tachometer,

check the shoe to see if it turns freely on its pin. The shoe riding surface is good if (1) the wear or polishing is evenly distributed across the surface area, (2) the surface is square with the shoe, and (3) there is sufficient wall area between the riding surface and the retaining pin.

Use the other shoe surface or replace the calibrating lever assembly if any of the following conditions exist:

1. Wear is uneven and has created an angular area on part of the riding area of the shoe.
2. Wear is heavy and one end of the shoe is tapered or wedged shaped.
3. Shoe is slightly worn.

If any of the following conditions exist, in addition to those mentioned previously, replace the calibrating lever assembly:

1. Hub is loose on the stationary member.
2. Adjusting screw is stripped or broken.
3. Shoe is broken or severely worn.
4. Shoe is binding on the pin or the pin is bent.
5. Head or setscrew is broken off in the hub.
6. Threads in the hub are stripped.
7. Calibrating lever bent.

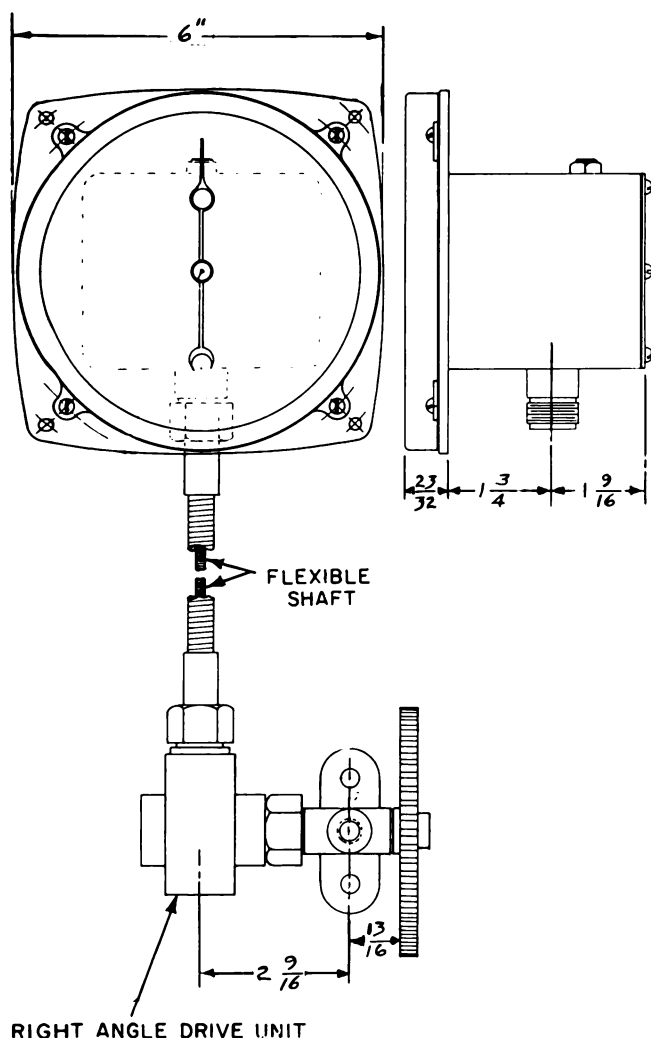


Figure 8-4.—Diagram of parts of a mounted centrifugal tachometer.

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GOVERNOR SUSPENSION BEARINGS

When examining the governor suspension bearings, remove the drive shaft from the tachometer, see that the shoe is not touching the disk, and with a slight amount of end play in the spindle, spin the governor assembly.

If the governor assembly does not spin freely, or feels or sounds rough, clean or replace the parts as required.

The ball bearings should be replaced if they are worn, scored, have flat spots, and are discolored. The bearing races or cups should be replaced if they are severely worn or scored.

Disassembly Procedures for Fixed Centrifugal Tachometers

To disassemble a fixed centrifugal tachometer, proceed as follows:

1. Remove the bezel and lens from the movement plate.
 2. Remove the pointer.
 3. Remove the dial.
 4. Remove the case.
 5. Remove the frame from the movement plate.
 6. Remove the drive shaft.
 7. Remove the governor assembly and be sure to note the number of ball bearings in the upper and lower ball race cups.
- EXAMPLE: Generally speaking, most tachometers have more ball bearings in the upper ball race than in the lower ball race.
8. Remove the drive shaft.

Reassembly Procedures for Fixed Centrifugal Tachometers

To reassemble a fixed centrifugal tachometer, proceed as follows:

1. Replace the drive shaft assembly.
2. Replace the ball bearings in the upper and lower ball race.
 - a. Apply a small amount of grease to the upper and lower ball races. (This aids in the replacement of the ball bearings.)
 - b. Make sure the correct number of ball bearings is in the upper and lower races.
3. Replace the governor assembly.
4. Set the governor end play. Adjust the upper ball race in or out until a very small amount of end play can be felt.
5. Replace the calibrating lever assembly.
6. Replace the frame on the movement plate, ensuring that the calibrating lever shoe is in its proper position between the flanges of the lower governor spindles.
7. Replace the case.
8. Replace the dial.
9. Replace the pointer.
10. Replace the bezel and lens.

Cleaning

To clean a centrifugal tachometer, the equipment to be used must be taken into consideration. Some shops have ultrasonic cleaners; a

complete disassembly is generally not necessary with this type.

Other shops may have clock type cleaning machines, which require additional disassembly to provide thorough cleaning. Mainly, cleaning steps should be taken to ensure that all old grease, oil and dirt, and other foreign matter are removed. Finally, depending on the solution used for cleaning, all parts should be completely rinsed and dried. (NOTE: Do not put the dial in the cleaning machine.)

Preventive Maintenance and Lubrication

In general, preventive maintenance means keeping the instruments clean, free running, and properly lubricated. A most important function in servicing a tachometer is proper lubrication. Experience has taught that the majority of repair jobs on tachometers could have been avoided if the instrument had been properly installed, serviced at regular intervals (500 operational hours), and lubricated properly.

Depending on the part, too much, too little, or no lubrication are all considered bad conditions which should be avoided. Too much lubrication may create a condition that causes sluggish action of parts. All moving parts of a tachometer should have some lubrication except where adhesion is a factor. Oil can create adhesion or a suction between parts that slide on flat surfaces. With age, some grease becomes hard and gummy. In addition, oil serves to collect dirt and dust. Another point to remember is that no lubrication causes friction and friction means wear.

Lubricate in accordance with manufacturers recommendations when technical manuals are available. Otherwise lubricate or observe instructions as follows:

1. Use only one drop of the correct oil in a bearing, as this is sufficient for proper lubrication, and is all the bearing will retain.
2. Use grease sparingly to prevent smearing or throwing to adjacent parts that would become sluggish if grease is allowed to get on them.
3. After lubrication is completed, wipe off any excess with a rag.
4. As far as the GOVERNOR is concerned, do not for any reason ever oil, or otherwise lubricate, the surface of the GOVERNOR SPINDLE over which the disk travels. Do not lubricate any other part of the governor assembly.

5. As far as the DRIVE SHAFT is concerned, apply a light coat of grease to the ball bearings and the bearing race, and a very slight amount of grease to the drive shaft gear.

6. For MOVEMENT ASSEMBLIES, apply a very small amount of clock oil to the bearing holes in the bridge and movement plate. Do not oil the sector or pinion gear teeth.

7. No lubrication is required for the CALIBRATING LEVER.

8. For GOVERNOR SUSPENSION BEARINGS, apply a light coating of grease in the spindle hole and around the race of each ball cup.

TACHOMETER TESTING EQUIPMENT

When high accuracy in the measurement of rotating speed is required, a tachometer must be calibrated against an accurate standard. One way to calibrate a direct reading mechanical tachometer is to drive it with a motor capable of being run at a constant and controllable speed. The speed is measured by means of a positive driven standard instrument. A tachometer is attached to the drive pad mounts. After the motor is energized, rotating movement is transmitted (through a belt system) to the pad mounts and ultimately to the tachometer. The speed is indicated on a positive drive stroboscope and tube.

Description and Nomenclature

The purpose of this section is to familiarize you with the nomenclature of the important parts and accessories of the tachometer tester. This information is presented briefly in the paragraphs which follow.

1. The main power switch is located inside the tester; in the back of the cabinet.
2. STOP and START pushbuttons.
3. The ratiotrol is a 10-turn rheostat with vernier, which controls the motor rpm.
4. The master tachometer enables the operator to interpret the stroboscope disk speed. The three scale ranges are: (1) 0 to 2,000, (2) 0 to 5,000, and (3) 0 to 10,000. The master tachometer indicates the approximate speed of the drive pads, to which the tachometer is attached.
5. The range selector is used to select the correct scale range on the master tachometer.

(LOW, MEDIUM, and HIGH). The range selector does not affect the motor rpm. For highest interpretation accuracy, the lowest range possible should be selected.

6. The master speed indicator or standard tachometer has the following parts:

a. The stroboscope disk, attached to the motor, has four separate black and white bands.

b. The strobotron tube limits successive timed light flashes. When the disk rotates, it is illuminated by the intermittent flashes from the strobotron tube.

When the rpm of the motor and the flashes of the light are synchronized, certain bands on the disk appear to be stopped. The outer band stops every 150 drive pad rpm. The second band stops every 300 drive pad rpm. The third band stops every 600 drive pad rpm. The fourth band stops every 1,200 drive pad rpm. The combination of these four bands and the master tachometer greatly simplifies the interpretation of the correct speed.

7. The strob ON and OFF switch should be turned on only while synchronizing the speeds. (The strobotron tube has a limited life.)

8. The fuse and holder is referred to as a SLO-BLO type fuse with a 0.1 amperage rating. It is used for the strobotron tube.

9. There are three drive pad mounts used for attaching the test instrument.

Operation

The tachometer tester, shown in figure 8-5 is capable of calibrating electrical, as well as mechanical tachometers. (NOTE: This is a typical tester used in the main shop of a naval ship such as the USS Cascade.)

To operate the tester, proceed as follows:

1. Ensure that the speed control knob is set at zero, (fully counterclockwise).
2. Push the start button.
3. Adjust the speed control knob to the desired appropriate setting.
4. Turn the strob-switch ON.
5. Adjust the speed control knob until the correct band or bands appear to be stopped.

To secure the tester, proceed as follows:

1. Turn the strob-switch OFF.
2. Turn the speed control knob fully counterclockwise, or OFF.
3. Push the stop button to secure the tester.

Maintenance

If the strobotron tube suddenly stops operating, check the fuse and replace, if necessary. An electrician should repair broken lead wires and check for any electrical trouble in the motor or control unit.

If the motor runs and the master tachometer and drive pads do not operate, the drive belt is probably broken and should be replaced.

Safety Precautions

The following safety precautions must be observed when operating a tachometer tester:

1. Avoid contact with electrical conductors.
2. Don't use electrical equipment with worn or frayed insulators.
3. Ensure that the electrical equipment is grounded.
4. Lead wire should not be kinked, cut, or in contact with oil, grease, or other chemicals.

CALIBRATION

Calibration of tachometers is a delicate operation and should only be undertaken by

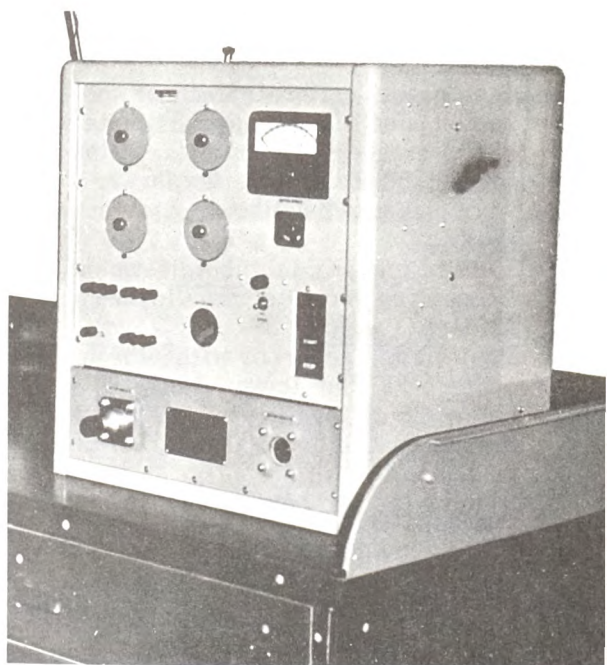


Figure 8-5.—Tachometer tester (main shop)

personnel familiar with the equipment and preferably with the aid of complete manufacturers' instructions for the calibration device and tachometer.

Calibration of a tachometer means the adjustment of its mechanism in such manner that the readings of the instrument agree with known and accurate standards. This is not an easy job, unless you are well trained in the procedure for calibrating a tachometer. The calibration and adjustment procedure which follows is typical for Jones Motrola tachometers. Procedures for other tachometers can be obtained from the manufacturer's technical manual for the specific equipment.

If the tachometer has been disassembled, part(s) replaced, or the adjustments are loose, the following initial adjustments must be made before starting calibration procedures.

1. Establish the Range Initial Adjustment.
 - a. The range initial adjustment is only necessary if a new calibrating lever has been installed.
 - b. Turn the calibrating lever adjusting screw until the space between the two brass hubs is approximately equal to that of the old calibrating lever which was replaced.
2. Starting Point Initial Adjustment.
 - a. Loosen the two calibrating lever set-screws.
 - b. Rotate the calibrating lever on the sector staff until an approximate 45° angle exists between the movement bridge and the calibrating lever.
 - c. Tighten the two calibrating lever set-screws.
3. Establish Linearity Initial Adjustment.
 - a. Loosen the two setscrews in the upper spider.
 - b. Position the governor so that the upper surface of the lower flange is just below the calibrating lever shoe when the calibrating lever is in its bottomed position.
 - c. Tighten the two setscrews in the upper spider.
4. Zero the Test Instrument
 - a. Place the pointer on the pinion shaft at a point 90° in a clockwise direction from the lowest dial indication.
 - b. Exerting gentle pressure on the hub, turn the pointer in a counterclockwise direction.
- c. Stop turning the pointer when it has reached the lowest dial indication.
- d. Seat the pointer on the pinion shaft.
- e. Test the zero indication a few times by moving the pointer off zero, with your finger, about 3/4 of the dial, and let it fall back to zero.
- f. If the pointer does not indicate the lowest dial indication or zero, remove the pointer with a pointer puller, and repeat steps a through d.

NOTE: The selection of any nominal value is dependent upon the ratio of the tachometer and the multiples of 150 rpm output speed of the tachometer tester.

The DRIVE RATIO is the relationship of the input speed applied at the drive connection to that indicated at the dial. **EXAMPLE:** A drive ratio of 1-2 means that the instrument will indicate twice the speed applied at the drive connection. A 1-4 notation would mean the instrument is indicating four times its driven speed.

A drive ratio notation of 2-1 means just the opposite, that the instrument is indicating one-half the speed applied to the drive connection.

The drive ratio is sometimes expressed as: "Runs 3 times engine speed." This means that the tachometer has a 1 to 3 ratio. The drive ratio is generally stamped on the name plate of the tachometer.

5. Establish the Starting Point
 - a. Select a nominal value that is approximately 20 to 25 percent of full scale indication of the test instrument.
 - b. This nominal value is known as the starting point.
 - c. Increase the rpm until the standard tachometer indicates the starting point.
 - d. Record the indication of the test instrument.
 - e. Decrease the rpm until the standard tachometer indicates zero.
 - f. Analyze the error recorded from the test instrument.

If the pointer indicates a reading above the starting point, proceed as follows:

- (1) Loosen the allen setscrew in the calibrating lever.
- (2) Adjust the round-head setscrew so that it is just snug against the sector shaft.

- (3) Reposition the calibrating lever on the sector shaft by holding the sector and rotating the calibrating lever clockwise.
- (4) This adjustment raises the position of the calibrating lever shoe in relation to the upper surface of the lower flange of the governor disk. In other words, the disk picks up the shoe later than it did previously.

If the pointer indicates a value below the starting point, reposition the calibrating lever on the sector shaft by rotating it counterclockwise.

6. Range and Linearity Test (Up Scale)

- a. Select as many as possible approximately equally spaced nominal values covering the span of the test instrument.
 - (1) The first nominal value is the starting point.
 - (2) The last nominal value is approximately 90 percent of full scale indication.
- b. Record the values in increasing order.
- c. Adjust the ratiotrol so that the rpm of the tachometer tester increases slowly.
- d. When the first nominal value is indicated by the standard tachometer, record the indication of the instrument.
- e. The nominal value must be approached in the direction of increasing rpm.
- f. If the rpm of the standard tachometer is increased above the nominal selected, decrease the rpm and repeat steps "c" and "d" of this procedure (6).
- g. Repeat steps "c" through "f" (of this procedure) for each remaining calibration point in increasing order listed for this test.

7. Hysteresis Test (down scale)

- a. Record the nominal values selected in step "4" (zero the Test Instrument) in decreasing order.
- b. Adjust the ratiotrol so that the rpm of the tachometer tester decreases slowly.
- c. When the highest nominal value selected is indicated by the standard tachometer, record the indication of the test instrument.

- d. The nominal value must be approached in the direction of decreasing rpm.
- e. If the rpm of the standard tachometer is decreased below the nominal value selected, increase the rpm and repeat steps "b" and "c" of this procedure (7).
- f. Repeat steps "c" through "e" (of this procedure) for each remaining calibration point in decreasing order listed for this test.

NOTE: Verify that the values recorded from the Hysteresis Test are within tolerance of those recorded from the Range and Linearity Test. If the values recorded from both tests are not within tolerance, repeat the calibration.

8. Range Adjustment.

- a. Analyze the error recorded from the range and linearity test. For example, as the rpm was increased from the starting point, the pointer on the test instrument indicated an increasing loss at the nominal values.
- b. To correct for an increasing loss situation, turn the calibrating lever adjusting screw counterclockwise.
- c. If the pointer on the test instrument indicated an increasing gain at nominal values as the rpm was increased from the starting point, turn the calibrating lever adjusting screw clockwise to correct for an increasing gain situation.

9. Linearity Adjustment

- a. Analyze the error recorded from the range and linearity test.
- b. If any of the following conditions exist, lower the governor:

	<u>Low 1/3</u> <u>of Dial</u>	<u>Middle 1/3</u> <u>of Dial</u>	<u>High 1/3</u> <u>of Dial</u>
(1)	Gain	On	Gain
(2)	Loss	On	Gain
(3)	Loss	Loss	On

- c. If any of the following conditions exist, raise the governor:

	<u>Low 1/3</u> <u>of Dial</u>	<u>Middle 1/3</u> <u>of Dial</u>	<u>High 1/3</u> <u>of Dial</u>
(1)	Loss	On	Loss
(2)	Gain	On	Loss
(3)	Gain	Gain	On

(NOTE: The indications in the center 1/3 of dial are approximate. After each range and parity adjustment, the starting point must be established. Correlate between the range and parity adjustments until the test instrument within tolerance.)

d. Tighten the calibrating lever set-screw, (NOTE: Apply the appropriate calibration label, tag, or both in a conspicuous position on test instrument.)

PORTABLE CENTRIFUGAL TACHOMETERS

Portable centrifugal tachometers manufactured for the Navy are single-range and multiple-range. These tachometers contain in a portable, hand-held, portable metal case the mechanism necessary to convert, by means of centrifugal governor, continuous rotary motion to angular displacement, shown on the tachometer dial in rpm or fpm. They are designed to indicate continuously instantaneous values of speed during the period their outer drive shafts are engaged with rotating shafts (motors,). Provision is made in the mechanism of each tachometer for the retention of its pointer indication on the dial, upon the disengagement of the outer drive shaft from the rotating shaft.

age

A multiple-range, portable, centrifugal tachometer has three ranges: low, 50 to 500 rpm; medium, 500 to 5,000 rpm; and high, 5,000 to 10,000 rpm.

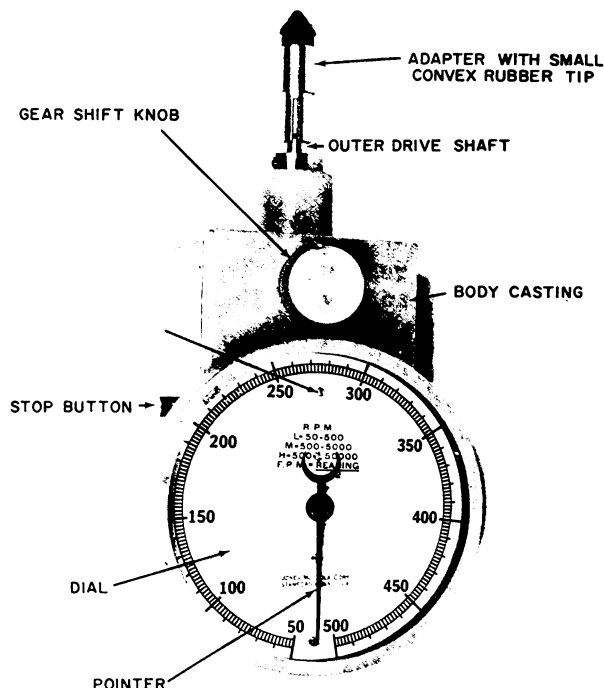
The tachometer shown in figure 8-6 is a multiple-range type. Note the control knob just above the dial. It has the letters H, M, and L to indicate the three different ranges. There are also three dots opposite each other. The attachments for this tachometer are contained in the case.

Allowable Error

The allowable error for centrifugal-type, portable tachometers may not be greater than 1 percent of the full scale reading at any ambient temperature between 40° F and 130° F when in normal (horizontal or vertical) operating position.

Readings with Portable Centrifugal Tachometers

To take a reading, select the proper tip. Different types of tips include:



61.21X

Figure 8-6.—Front view of a portable multiple-range centrifugal tachometer.

1. Small, convex, rubber tip (for shafts with a small center hole).
2. Large, convex, rubber tip (for shafts with a large center hole).
3. Concave, rubber tip (for shafts with pointed ends).
4. Triangular, steel tip (for shafts with no center holes).
5. Rubber-tired wheel (6-inch circumference) for measuring surface speed in fpm. (Divide dial reading by 2 to get correct surface speed in fpm).
6. Extension rod (4-inch length).

Operation

After you secure the proper tip on the outer drive shaft of a multiple-range, centrifugal tachometer, turn the gear shift knob until the letter indicating the range desired is in line with the dot on the tachometer body. NOTE: If you are not certain about the speed range to use, start with the high range and then go to the

medium and low ranges, in this order. Over-speeding can destroy gears on the low range mechanism. Figure 8-7 shows the interior mechanisms of a portable multiple-range centrifugal tachometer.)

With the tachometer gear shift knob set at the desired range, place the drive tip accurately in line with the center of the shaft whose speed you desire to measure and note the reading on

the dial. Hold the tachometer in position long enough to be certain of the reading. **CAUTION:** Unless you hold the tachometer tip directly in the center of the shaft, your reading will not be accurate—it will indicate a speed greater than the true speed of the shaft undergoing a test.

If you wish to hold the pointer at the maximum speed recorded by a rotating shaft, press the button on the left side of the case (face up and

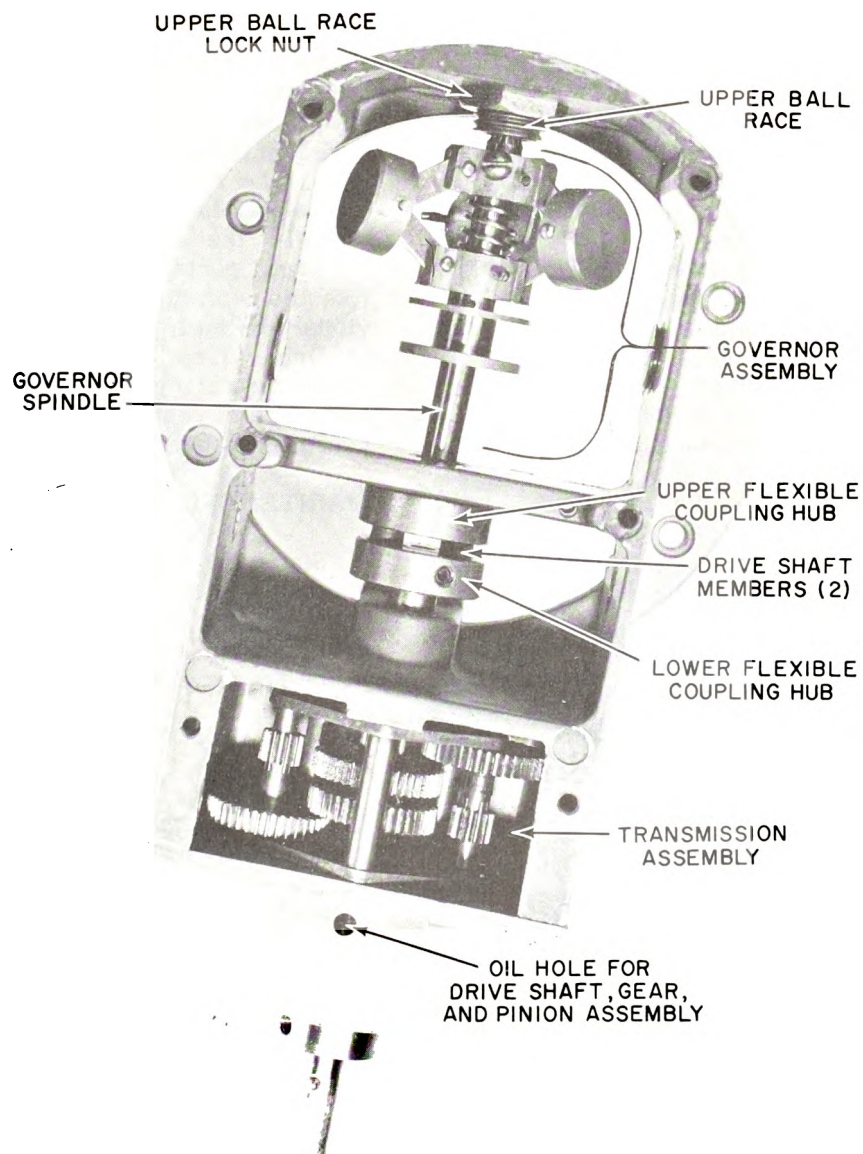


Figure 8-7.—Interior mechanism of a portable multiple-range centrifugal tachometer. 61.22

er drive shaft front). Press the button on the right side of the case to return the pointer back to zero.

CAUTION: Do not change from one speed range to another while you have the drive tip of tachometer in contact with a rotating shaft—a sudden change in speed may damage gears or break a gear shaft.

Maintenance

Cleaning and repair of portable centrifugal tachometers is performed in the same manner as for the fixed centrifugal tachometer.

CHRONOMETRIC TACHOMETERS

With this instrument, rotary speed of any accessible shaft is obtained by taking the average speed over a short period of time. A portable chronometric tachometer, shown in figure 8-8, is a combination timepiece and mechanical revolution counter with a mechanism for simultaneously starting and stopping the two. Rotary motion is converted into angular displacement and shown on a dial scale in rpm.



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Figure 8-8.—Portable chronometric tachometer.

RANGE AND ALLOWABLE ERROR

The range of the chronometric is 0 to 10,000 rpm and from 0 to 3,000 fpm, with an allowable error of not more than 10 rpm for scale readings from 500 to 1,000 rpm and 0.5 percent of full scale readings from 1,000 rpm to the maximum scale reading.

READINGS WITH A CHRONOMETRIC TACHOMETER

To take a reading, place the spindle tip of the tachometer accurately on the center of the shaft. Press the starting button or lever. Then release the button. Within six seconds the instrument will automatically shut off and register rpm based on the average speed during its operating time. The reading is retained on the dial until the pointer is returned to zero by a reset button (usually the same as the starting button).

Each portable, chronometric tachometer, like the centrifugal tachometer, discussed previously in the chapter, is supplied with a number of Drive Tips. Portable tachometers of the chronometric or centrifugal type are used for intermittent readings only, and are not used for continuous operation.

MAINTENANCE

Since the mechanism of a chronometric tachometer is similar to that of a watch, any required repair or adjustment should be performed by an accomplished Instrumentman experienced in the repair of watches.

RESONANT TACHOMETERS

The resonant tachometer most commonly used by the Navy is the vibrating reed type, shown in figure 8-9. This type tachometer is used to measure rpm when (1) the rotating shaft is not readily accessible and (2) the extra load of a rotating tachometer would modify the shaft speed. Two types of resonant tachometers are the portable and fixed; both types operate in the same manner.

The vibrating reed tachometer, which may be mounted or held by hand on a motor, operates by contact with the machine under test. The free ends of accurately tuned reeds are observed against a scale calibrated in rpm. Speed is indicated by the reed tuned nearest the vibrational frequency of the machine. This reed

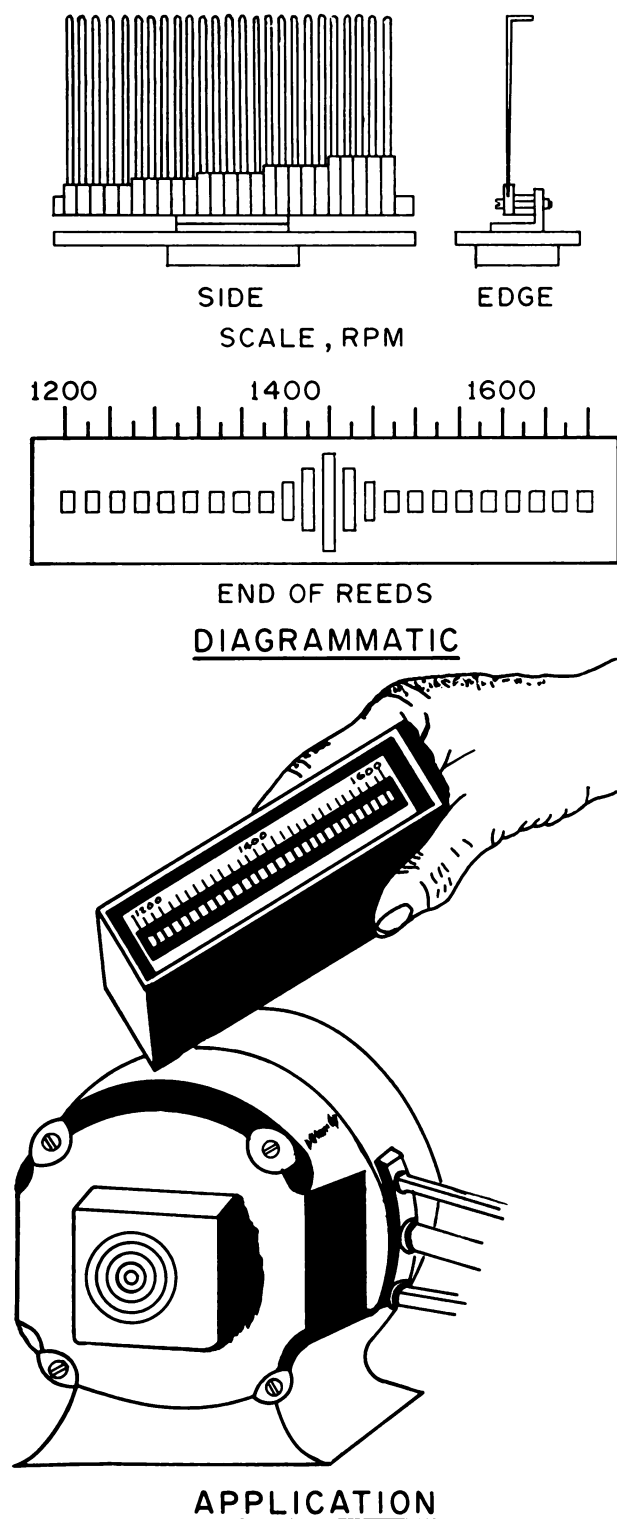


Figure 8-9.—Vibrating reed tachometer.

vibrates at maximum amplitude. The instrument has relatively narrow speed ranges per single unit. Accuracy depends on the interval between reeds and the ability of the operator to interpolate in these intervals. Additional information concerning operating principles is covered in the next section.

OPERATING PRINCIPLES

Vibrating reed tachometers operate on the concept of simple harmonic motion and vibration. Harmonic motion is a regular periodic motion, such as the movement of a pendulum or child's swing. The period of the motion is the time required for one complete cycle or oscillation. The number of cycles or oscillations in a given time is called frequency.

The natural frequency of an object may be altered by changing either its length or mass. The natural frequency of the reed may be increased by making it shorter or lighter. Conversely, the natural frequency may be lowered by increasing its length and making it heavier.

The vibrating reed tachometer consists of a number of reeds which have different natural frequencies, as shown in figure 8-10. The reeds are lined up sequentially, in such a way that the edge of each reed is visible through a window. All the reeds are connected to a common block in the tachometer which serves to couple the driving force.

The tachometer is held against the housing of the rotating device. The vibrations from the rotating device are thus mechanically coupled to the holding block and to the reeds. The reed which has a natural frequency closest to the

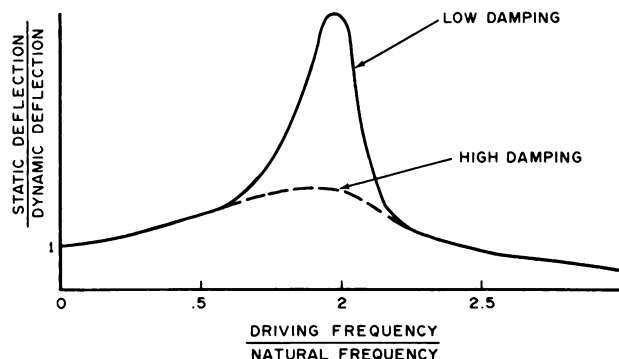


Figure 8-10.—Oscillation amplitude vs. driving frequency.

vibrating block will be set into maximum vibration. Other reeds near the driving frequency will scillate somewhat, but at a smaller amplitude. Thus, by observing the amplitude of the reeds, the rotational speed of the device under test is measured.

CARE AND MAINTENANCE

The vibrating reed tachometer has no gears or couplings, and requires no oiling and very little maintenance. The repair that can be performed by the Instrumentman is to replace the window glass.

ELECTRICAL TACHOMETERS

A portable electrical tachometer is shown in figure 8-11. These instruments are used to indicate the speed of accessible shafts by either the electrical reactance principle or the magneto generator-voltmeter principle. Each type consists of (1) a head component to place in contact with the rotating objects, (2) an indicating component, and (3) a connecting electric cable.

The electrical reactance instrument is made in several styles and ranges, which, with adapters, has limits from a minimum of 20 rpm to

a maximum of 100,000 rpm. The allowable error is not more than one percent of full scale reading.

MISCELLANEOUS TYPES

The miscellaneous types of electrical tachometers which you may come in contact with are the magneto generator-voltmeter type, the alternating current voltage responsive type, the frequency responsive type, and the frequency sensitive type. These tachometers are also classified as fixed (continuous duty) tachometers. Information concerning the operation and maintenance of these tachometers can be obtained from the manufacturer's technical manual for the specific unit.

PROPELLER REVOLUTION INDICATORS

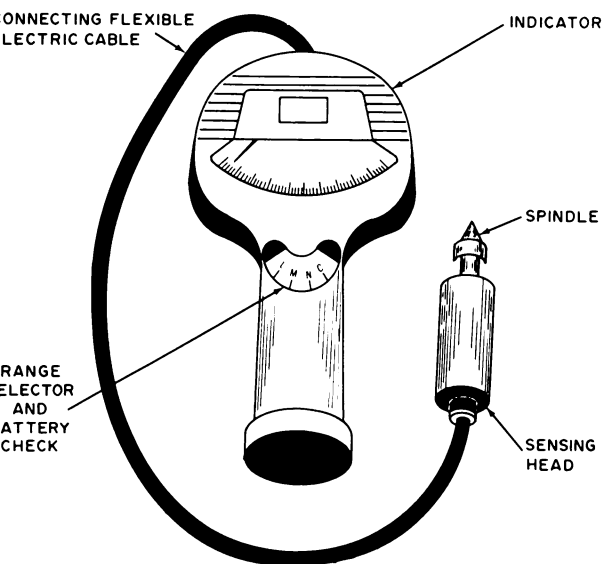
The electric tachometer used by the Navy for propeller revolution indication on combatant ships and large auxiliaries consists of a synchro-generator transmitter, a synchro motor indicator-transmitter, and one or more repeater indicators. The transmitter, which is similar to the synchro-generator, is either gear driven from the propeller shaft or directly coupled to the end of the propulsion machinery stub shaft.

CARE AND MAINTENANCE

Repair of electrical tachometers should be made by or with the consultation of an Electrician's Mate. When irregular operation occurs on gear driven counters, check the gears for tightness, wear, and proper mesh.

STROBOSCOPIC TACHOMETERS

The stroboscope is a device which uses a flashing light (strobe) to freeze or slow down the motion of a rotating part. (This method of measurement is analogous to the electrical pulse method except that there is no counting involved.) The measurement is made in terms of a pattern on the rotating part, as it appears when lighted by the strobe. When the pattern is stationary, the drift rate indicates the magnitude of the differences between the rate of the flashes and the rate of the rotating part. The direction of the drift indicates which rate is



61.172

Figure 8-11.—Portable electrical tachometer.

faster. A drift in the same direction as the rotation of the part indicates that the part is turning at a rate which is greater than the flash rate.

As far as care and maintenance are con-

cerned, stroboscopes require similar care and maintenance as for other ELECTRICAL tachometers, unless certain factors are specified for individual tachometers, in accordance with manufacturer's specifications.

CHAPTER 9

LIQUID LEVEL INDICATORS

In the engineering plant aboard ship, it is frequently necessary for operating personnel to know the level of various liquids in various locations. The level of the water in the ship's boilers is an example of a liquid level that must be known at all times, but there are other liquid levels that are also important—the level of fuel oil in service and stowage tanks, the level of water in deaerating feed tanks, the level of lubricating oil in the oil sumps of main and auxiliary machinery, and drains in various drain tanks.

A wide variety of devices, some of them simple and some complex, are available for measuring liquid level. Some measure liquid level quite directly by measuring the height of a column of liquid. Others measure pressure, volume, or some other property of the liquid from which we may then infer liquid level.

Without these measuring instruments, required for the measurement of oil, gasoline, and water in storage tanks, engineering and operating personnel could not plan for their supply needs wisely, and they would have to estimate the amount of liquid consumed from a tank during a definite period.

The instrument shop is responsible for the repair and maintenance of tank level indicators. Instrumentmen may also be required to install new or repaired instruments. This chapter provides general information on gage glasses, remote water level indicators for boilers, and hydrostatic and hydraulic gages employed aboard ship. Additional information concerning these instruments can be obtained from manufacturer's technical manuals and applicable NavShips publications.

MEASUREMENT OF LIQUID LEVEL

Liquid level may be measured directly, using the various level of liquid as the means

of obtaining a measurement; and indirectly, using a variable—which changes with liquid level—to drive a measuring mechanism. Sounding rules, gaging tapes, and tape and float gages are direct reading devices. Static head indicators and electrical indicators are indirect reading devices. Float actuated indicators may be either direct or indirect reading, depending on their construction and use.

As far as tank level indicators are concerned, level is usually sensed in the tank at either an air—liquid interface or liquid—liquid interface as in a compensated tank—a tank which contains two liquids of different specific gravities, such as gasoline and sea water. Sensors are available for operation in high pressure and low pressure tanks.

The ultimate reason for any tank liquid level measurement is the determination of how much of a given liquid has been used or remains in a tank. Since what is desired from level measurement is the amount of liquid in the tank by weight or volume, the linear level measurement obtained by a level indicator must be related to the geometrical configuration of the tank. In rectangular tanks, level and volume are linearly related, in odd-shaped tanks (the most common), volume must be determined at given increments as a function of level. Therefore, initial calibration of tank capacity gages or development of capacity tables and curves depends on tank geometry.

GAGE GLASSES

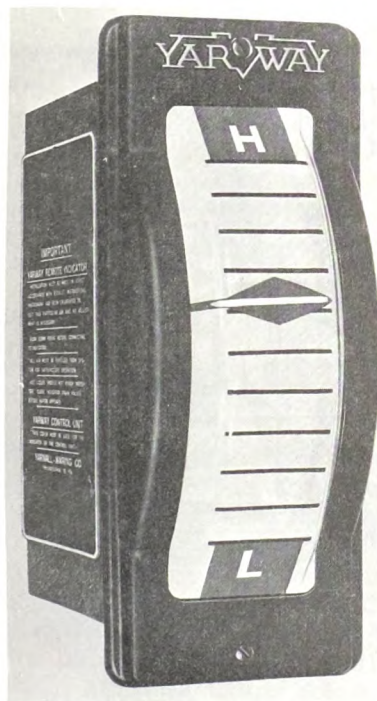
The gage glass is one of the simplest kinds of liquid level measuring devices and one that is very commonly used. Gage glasses are used on boilers, on deaerating feed tanks, on inspection tanks, and on other shipboard machinery. Basically, a gage glass is just one leg of a U-tube, with the other leg being the

tank, drum, or other vessel in which the liquid level is to be measured. The liquid level in the gage glass is thus the same as the liquid level in the tank or drum, and the reading can be made by direct visual observation. Gage glasses vary in details of construction, depending upon the pressure, temperature, and other service conditions they must withstand.

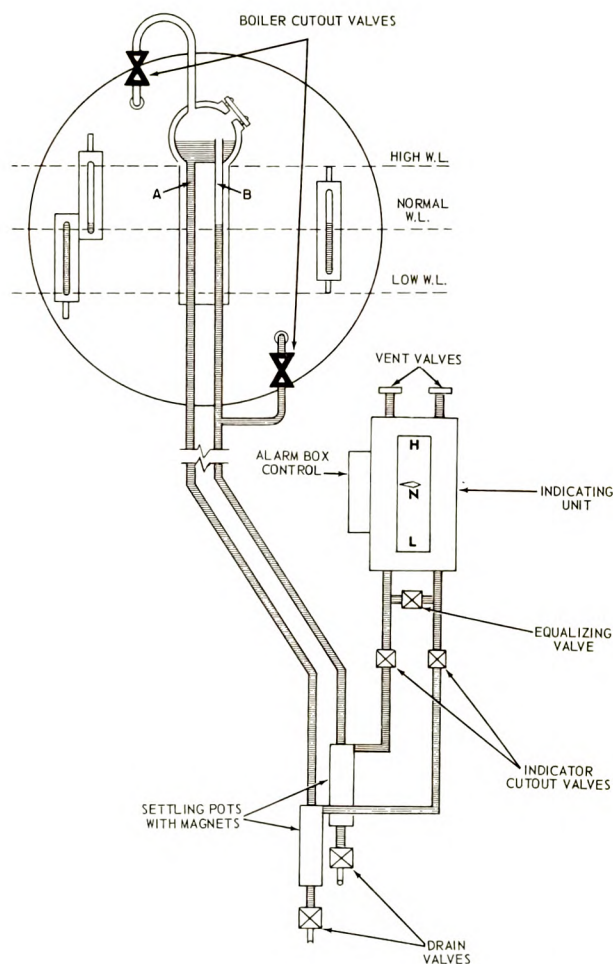
REMOTE WATER LEVEL INDICATORS FOR BOILERS

In addition to the gage glasses, some boilers have been equipped with remote water level indicators. The remote water level indicators are generally installed on the operating level of the boilers to provide the petty officer in charge with a readily obtainable reading of the water level in the steam drum of the boilers. Figure 9-1 illustrates one type of remote water level indicator.

Remote water level indicators are used on most ships to provide a means whereby the boiler water level may be observed from the lower level of the fireroom. The two types of



139.33
Figure 9-1.—Remote water level indicator.



98.97
Figure 9-2.—General arrangement of Yarway remote water level indicator.

remote water level indicators (Yarway and Jerguson) that are described here are in common use on combatant ships. A third type (Reliance) is used on some cargo ships and converted types. A fourth type (Bailey) is usually used where Bailey combustion and feed water controls are installed.

YARWAY REMOTE WATER LEVEL INDICATOR

The general arrangement of the Yarway remote water level indicator is shown in figure 9-2. The main parts of the unit are (1) the constant-head chamber, which is mounted on the end of the steam drum, as close as possible to the vertical centerline; (2) a graduated

indicator, which is usually mounted on an instrument panel; and (3) two reference legs, marked A and B in figure 9-2, that connect the constant-head chamber to the indicator.

A constant water level is maintained in leg A, since the water level in the constant-head chamber does not vary. The level in leg B is free to fluctuate with changes in steam drum water level. The upper hemisphere of the constant-head chamber is connected to the steam drum at a point above the highest water level to be indicated; because of this connection, boiler pressure is exerted equally upon the water in the two legs. The variable leg B is connected to the steam drum at a point below the lowest water level to be indicated; because of this connection, the water level in leg B is equalized with the water level in the steam drum.

As you can see in figure 9-2, each leg is connected by piping to the indicator. In the indicator, the two columns of water terminate upon opposite sides of a diaphragm.

The pointer of the indicator moves over an illuminated scale that shows low, normal, and high water levels. The indicating unit of the remote water level indicator includes two magnetically actuated switches that operate a warning horn when the water level in the steam drum is too high or too low. (NOTE: The indicating unit of the remote water level indicator can also be provided with an accessory to operate a remote electrical slave unit which can be mounted outside the boiler room, if desired.)

The manufacturer's instructions should be followed in replacing light bulbs, diaphragms, deflection plates, or other parts of the indicator. The remote water level indicator is not likely to require recalibration; if the need should arise, however, the indicator may be recalibrated by the procedures described for the Yarway superheater steam flow indicator in NavShips publications. Additional information on steam flow indicators can be obtained from manufacturer's technical manuals.

The remote water level indicator requires blowdown occasionally. When blowing down the indicator, be very careful to see that the hot boiler water does not reach the indicator. The appearance of vapor in the blowdown discharge should serve as a warning to close the drain valves instantly.

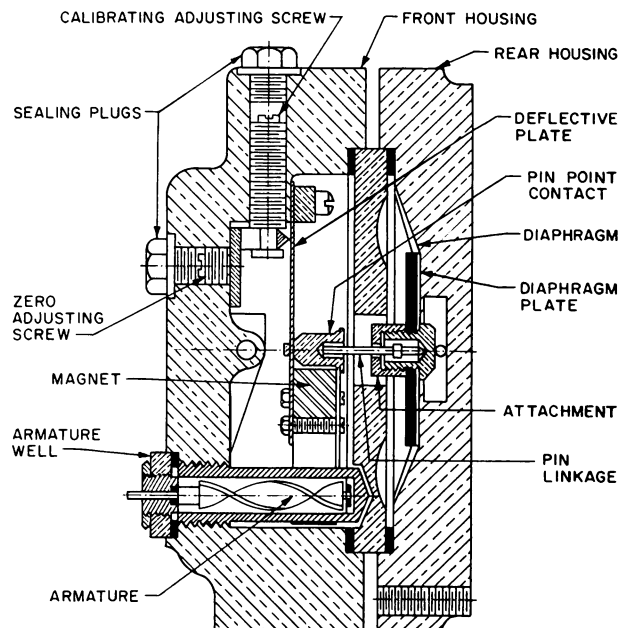
In order to better understand the nomenclature and function of the component parts of a

Yarway remote water level indicator, refer to figure 9-3 which illustrates a sectional view of the unit. The diaphragm is connected by a pin linkage to a deflection plate which moves in sensitive response to the movement of the diaphragm.

A permanent horseshoe magnet is rigidly mounted on that side of the deflection plate which is free to move. The poles of the magnet straddle a tubular well (secured into and forming part of the housing) in which a spiral-shaped armature rolls in order to keep in alignment with the magnetic field between the poles of the magnet. Thus, a rotary motion is imparted to the armature mounting shaft; and the rotation of the shaft causes the pointer to move. The movement of the pointer registers instantly and accurately every change in boiler water level.

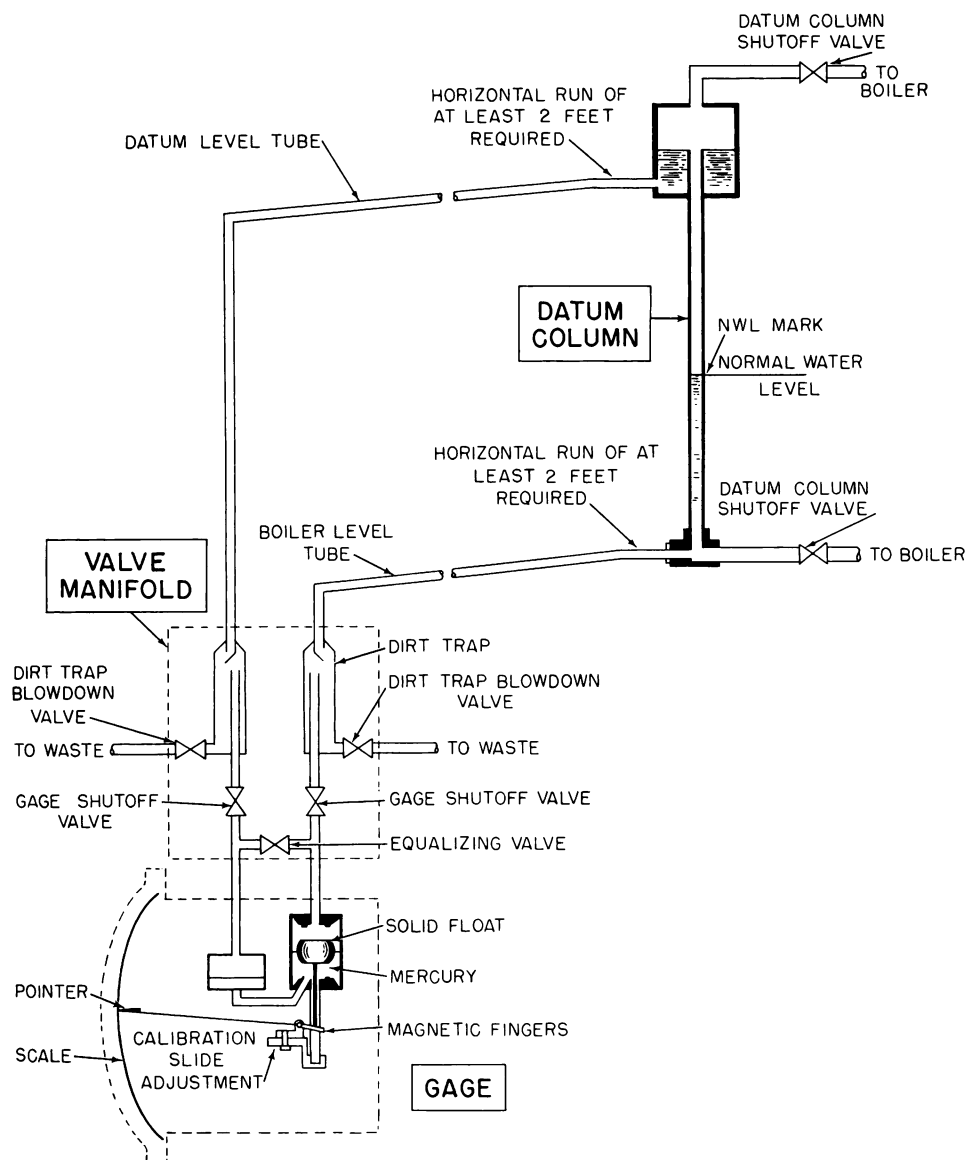
JERGUSON REMOTE WATER LEVEL INDICATOR

The general arrangement of the Jerguson remote water level indicator is shown in figure 9-4. Before being put into operation, the



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Figure 9-3.—Sectional view of Yarway remote water level indicator.



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Figure 9-4.—Jerguson remote water level indicator.

indicator must be filled with mercury and calibrated. After adding 5 pounds of mercury to the gage, and clear tap water until the gage is full, close the shutoff valves and the blowdown valves at the valve manifold. Open the valves between the datum column and the boiler. Then open the blowdown valves and flush the lines thoroughly with steam to remove all air and foreign matter. Allow the datum column and the lines to fill up with condensate. When the lines (up to about 3 feet from the datum column)

have cooled down to room temperature, you can assume that they have filled with condensate.

With the equalizing valve closed, open the gage shutoff valves. With the boiler water at normal level, the gage will read BELOW "N" on the scale because of the excess mercury in the gage. Drain mercury through the mercury bleeder valve until the pointer is at "N" on the scale.

Raise or lower the water level in the boiler to obtain a departure of at least 6 inches from

normal, as indicated by the water gage glass. Loosen the calibration slide lock screw, and adjust the calibration slide so that the pointer reading corresponds to the water gage glass reading. After making the calibration slide adjustment, back out the pointer arm locking screw and adjust the pointer length to clear both the scale and the window. The gage should now indicate the correct water level throughout its entire range.

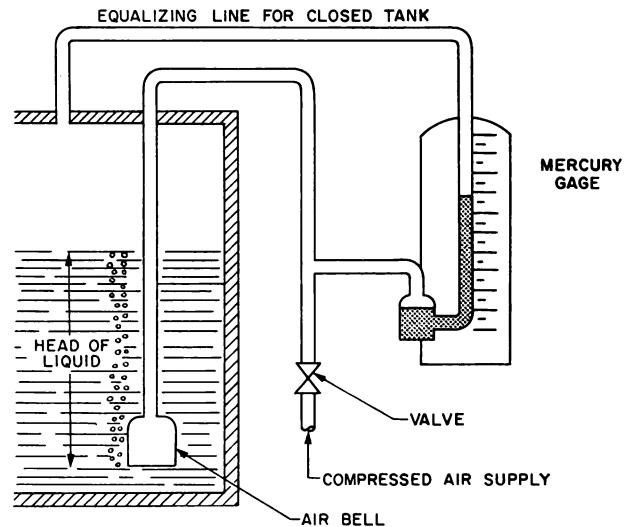
When the boiler is secured, be sure to close the valves between the datum column and the boiler. This precaution is necessary to prevent the carryover of excessive amounts of boiler compound or other foreign matter into the datum column.

STATIC HEAD (HYDROSTATIC) LIQUID LEVEL INDICATORS

Static head level indicating systems operate on the principle of balancing a head of liquid in a tank against a column of liquid in a manometer or against the pressure sensing element of a dial gage. The indicator may be calibrated in units of depth, weight, or volume of liquid. General accuracy of static head systems is plus or minus one minor scale division of the indicator. Three major types of static head systems are described in the sections which follow.

PNEUMATIC SYSTEMS

A typical arrangement of a simple pneumatic system is shown in figure 9-5. The sensing element is usually a pipe, known as an air bell, inserted in the tank and open at the bottom so that liquid in the tank may enter. The air bell is connected with lines leading to a compressed air supply on the manometer or gage bellows. When compressed air is introduced into the air bell, it pushes liquid in the bell out through the bottom. The amount of pressure developed at the bottom of the tank varies directly with the head of liquid in the tank. This is balanced by air pressure in the bell which increases only until it is equal to the head of the liquid. Additional air will bubble out through the bottom of the bell. Therefore, the indicator shows only a pressure equal to the head of the liquid in the tank. If the tank is closed, an equalizing line is provided from the top of the tank to the low pressure side of the manometer or to a sealed



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Figure 9-5.—Simple hydrostatic liquid level indicating system.

bellows housing. This prevents a loss of indicating fluid or element rupture when inadvertent overflow or excess pressurization of the tank occurs, and permits a true level indication when the contents of the tank are externally pressurized. Since the bottom of the air bell is a small distance above the lowest point of the tank, the indicator is set to reflect this difference and give a true zero level reading. In addition to an indicator and air bell, the system generally consists of tubing and connections, tank top fittings, and a hand pump or compressed air supply and operating valve.

Pneumatic systems are specified for low and high pressure tank applications. For low pressure tanks the manually operated air pump, usually built integrally or mounted with the indicator, is generally used. For high pressure tanks a manual air pump or compressed air supply is used with a four-way operating valve which permits blowing out the air bell tubing and equalizing tubing without subjecting the indicator to the imposed pressure.

Systems may be used for intermittent or continuous automatic operation—for automatic operation, a compressed air supply is essential.

An internal draft gage system, shown in figure 9-6, is used to obtain a reading of the ship's draft inside the ship whenever it is impractical to observe hull draft marks. A sea chest, located at the bottom of the hull, is

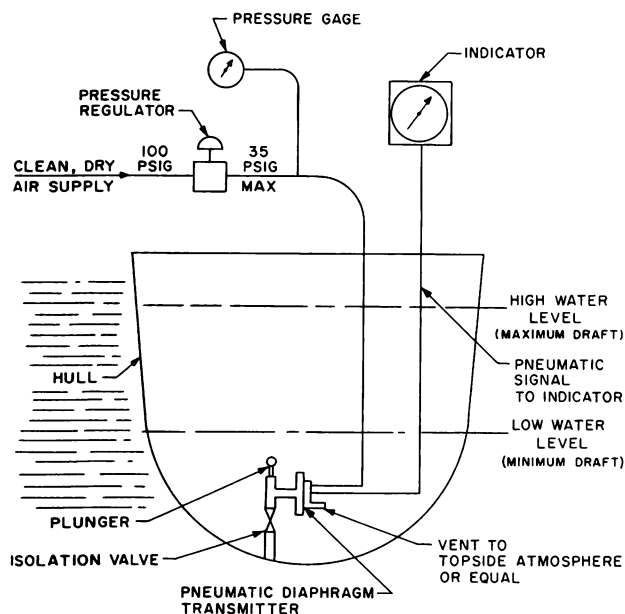
connected to the air supply and indicator. To prevent plugging of the opening, a plunger is provided to periodically eject barnacles and other objectionable matter from the sea chest.

In addition to the air bell and internal draft gage systems, a tank top pressure system (shown in A of fig. 9-7) provides a continuous indication of the pressure in a compensated fuel tank. A pressure transmitter measures the pressure at the top of the tank and transmits an equal air pressure signal, equal to tank top pressure, to an indicator.

A continuously operating system (shown in B of fig. 9-7) provides a constant indication of the liquid level in a service tank where no possibility of tank top pressure exists in the tank. A pressure transmitter, located near or below the bottom of the tank, measures the liquid level in the tank and transmits an air pressure signal to one or more remote indicators. Gages are calibrated directly in gallons or pounds of fuel.

Operation

To take a tank level reading with an air bell type system having a hand pump and no operating valve, it is merely necessary to give the pump several strokes until the gage shows a steady reading, indicating that air is bubbling out from



61.175

Figure 9-6—Internal draft gage system.

the bottom of the bell, and the pressure head of liquid is being sensed. The gage line is branched directly off the pump—air bell line. A similar system, without an operating valve, operates in a like manner using a compressed air supply. For continuous level indication with this system, a constant compressed air supply is all that is required.

For a practical application concerning operation, refer to figure 9-8, which shows how a tank level indicator is installed. (The commercial name for the hydrostatic gage shown is Tank-o-meter.) The air supply for the indicator shown is from a hand pump. (The scale on the manometer may be graduated in units of depth, weight, or volume. Some gages, in fact, have two scales which show the contents of a tank in feet and also in gallons.)

The gage illustrated in figure 9-8 works in this manner: When the hand pump is operated, air is forced through connection A to the pressure pipe connected to the balance chamber in the bottom of the tank. Pressure exerted by the liquid in the tank on the air in the balance chamber through connection B is measured by the indicating mercury column. (NOTE: The balance chamber is located so that its orifice, or opening, is near the bottom of the tank.)

Pressure in the pipe increases only until it is equal to the head (H) of the liquid. Additional air bubbles out through the orifice in the balance chamber. The indicating column thus continues to rise only until it reaches a point corresponding to the head of liquid in the tank. Continued pumping has no effect on the reading on the gage.

Line C, connected with the column of mercury in the gage and the air space above the liquid in the tank, acts as a pressure equalizing line and guards against inaccurate readings when the tank is put under pressure or vacuum.

When the system is equipped with an operating valve, readings are taken as follows:

1. Move the operating valve (sometimes referred to as an air control valve) to the position marked "air" and charge the system by giving the hand pump several strokes. If the air is supplied by another source (compressed air from the ship's supply), leave the operating valve on "air" for approximately 10 seconds. If the air does not go through the line, it is probably blocked by an accumulation of gummed oil. Disconnect the line and flush it out with an approved solvent.

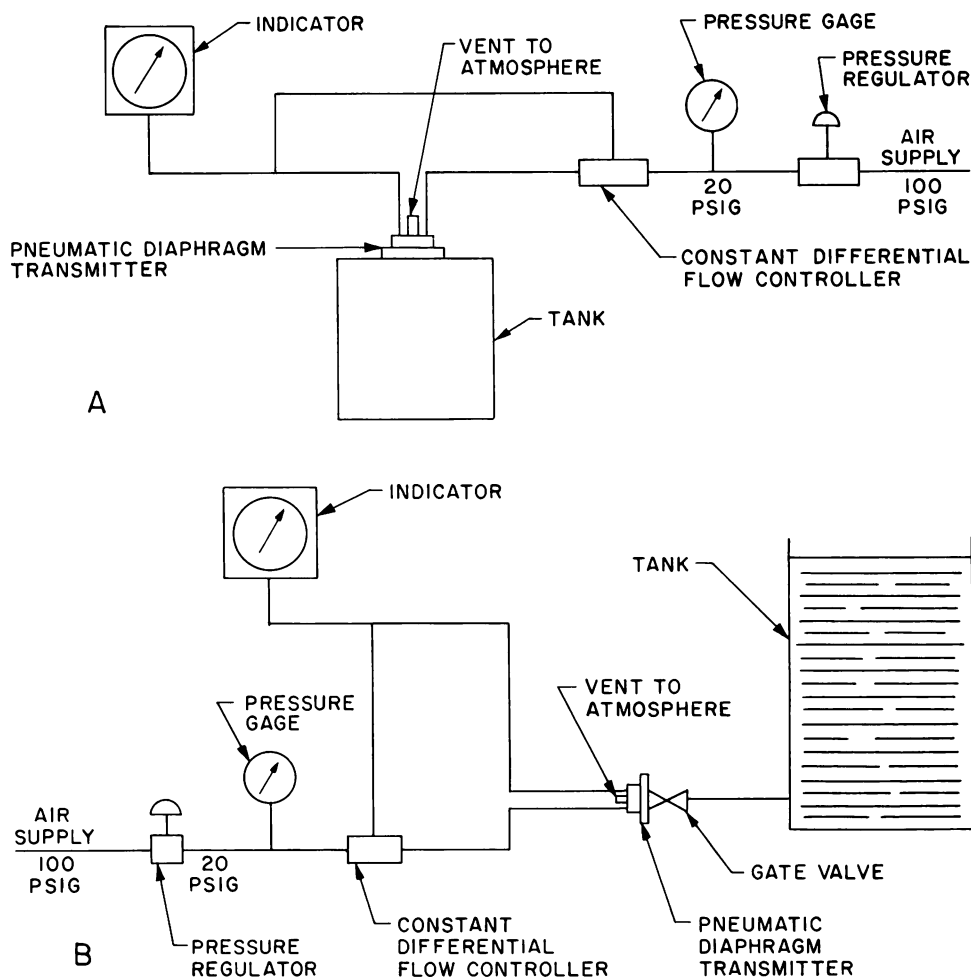


Figure 9-7.—A. Tank top pressure system; B. Continuously operating system.

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2. Move the operating valve to the position marked "shut" and allow it to remain in this position for several seconds to permit equalization of pressure throughout the system.

3. Move the operating valve to the position marked "gage" to allow either the mercury to rise in the tube or a dial indication.

4. Note the position of the mercury or pointer and repeat steps 1-3 mentioned previously. If the mercury then reads the same as the first time, the gage reading is correct. If the mercury gives a higher reading than the first time, there is an insufficient amount of air in the system. Repeat the first three steps and take another reading.

Additional Notes on Operation

Additional information concerning the operation of pneumatic static head level indicators is given in the paragraphs which follow.

For manometric indicators, or tank level indicator systems, read the top of the meniscus of the mercury. If the line of the tubing becomes obstructed or sufficient time is not allowed for the system to balance, the mercury will rise above the top graduation and enter the mercury catches. When the obstruction is removed and the system is full charged with air, the mercury will automatically return to the proper level.

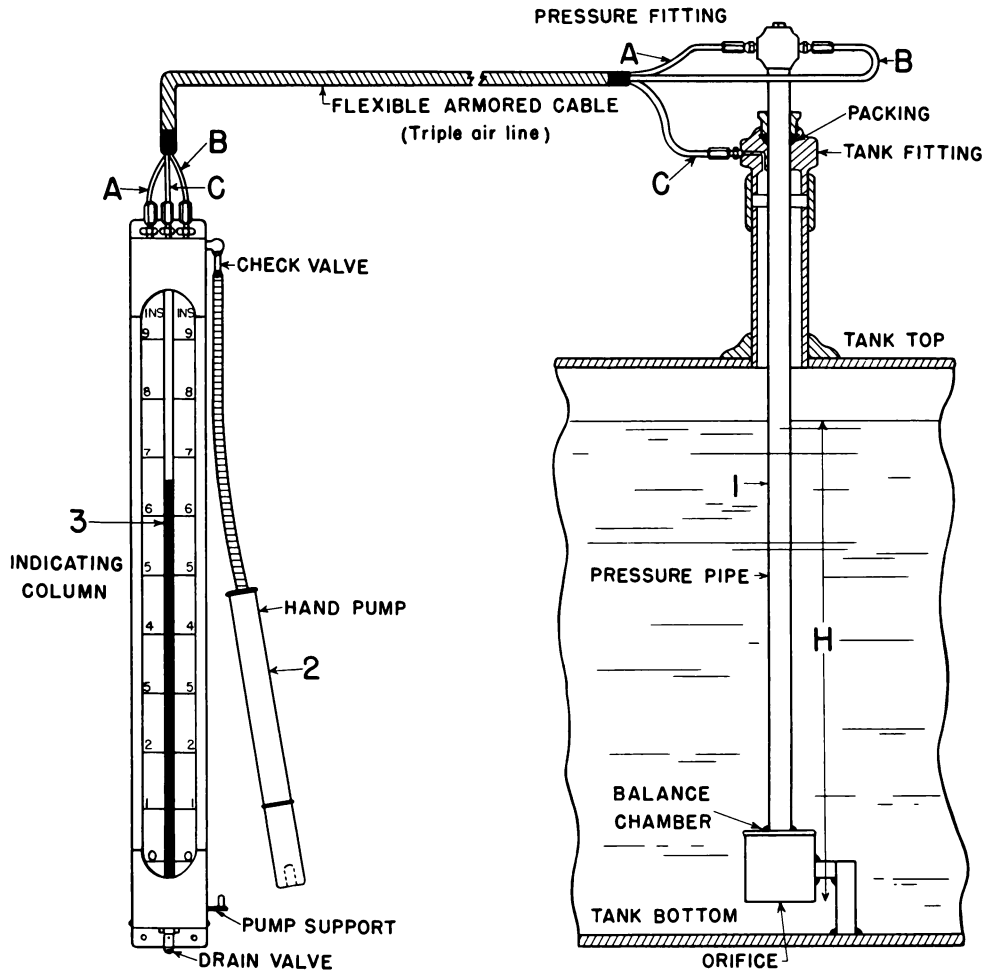


Figure 9-8.—Tank-o-meter installed in a tank.

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If after taking a reading, the level of the mercury (or the gage pointer) slowly drops while the level in the tank remains constant, there is probably a leak in the tubing between the gage and the balance chamber. The leak can be located by charging the system and applying soapy water to the lines and connections, and watching for bubbles.

When the apparatus is not in use or when the tank is empty, move the operating valve to the position marked "vent." When the operating valve is at "vent" position, the mercury or pointer should rest opposite the bottom graduation on the scale.

Keep the system charged with air during the entire time that the tank contains liquid.

The effective working pressure of tank level indicator systems is about 30 psig. If the air supply for the indicators comes from the ship's air system, reduce the pressure to 30 psi by means of a reducing valve. If the liquid in the tank is under pressure, the working pressure for the indicating system must be 20 psi above that in the tank.

If there is a radical change in the specific gravity of the fuel oil, particularly when the fuel is changed, a correction must be applied to the readings or a new scale installed.

Maintenance and Care

For oil tanks, if air cannot be blown through, the line is probably blocked by an accumulation

of gummed oil. Disconnect the line at the gage and clear it by flushing with kerosene.

As far as joints and fittings are concerned, practically the only pipe fittings on the lines of a tank level indicator system are unions of a special type. The unions can be taken apart and remade several times with no danger of leaking, if properly made up. Do not use solder, packing, or gaskets of any kind in making up the joints of either the copper or lead piping.

If the grease on the operating valve hardens, remove and clean the valve plug, and coat it with fresh grease.

Never remove the indicator scale from one tank level indicator and install it in the indicator of another tank, since the indicators are calibrated to give readings on an individual tank of certain size and shape. If the scale is used on a tank of dimensions other than for which it was calibrated, incorrect readings will result.

Calibration

Insofar as the proper operation of all tank level indicators depends upon the maintenance of a true hydrostatic balance between the head of the liquid and the indicating medium in the gage, correct readings will be obtained only when the scale is properly installed. The first step in adjusting the scale to the gage of a tank level indicator is to measure accurately the distance between the lowest point of the tank and the "zero line" of the measuring chamber or air bell—the point at which it is open to the tank. Having determined this distance, the amount of liquid remaining in the tank when the level has reached the zero line of the measuring chamber can be computed. The scale must then be adjusted so that when the level of the fluid in the tank drops to the zero line level, it will register the proper amount of liquid in the tank. If this procedure is not carried out and the scale is made to read zero when the level of the liquid reaches the zero line, the readings will all be in error an amount corresponding to the amount of liquid in the tank when the level reaches the zero line mark.

As an example, assume that a measuring chamber is secured in an oil tank on board ship with the zero line three inches above the lowest point of the tank. Then the scale should be cut off and placed on the gage so that the lowest graduation thereon will show the amount of oil in the tank when the oil level is three inches from the bottom of the tank.

Pressure elements used with level indicating systems may be calibrated as described for manometers and gages in chapter 9870 of NavShips Technical Manual.

WATER FILLED SYSTEMS

There are two major water filled systems which are classified according to their use: (1) Measurement of interface level of compensated tanks and (2) Measurement of level in high temperature water tanks.

In a water filled hydrostatic system for compensated tanks, where there are two immiscible liquids such as fuel oil and sea water, the system generally consists of a level indicator piped to in-tank upper and lower water reservoirs. Such a system is illustrated in figure 9-9. A remote indicator can also be used optionally. The indicators may be direct reading (in gallons of a specific fuel) or indirect whereby a numerical dial is checked against the capacity table of a given fuel to indicate the quantity in the tank. The pressure at the bottom of a tank depends on the height of liquid in the tank and the density of the liquid. If the tank is full of sea water, the pressure will be greater than if it were full of fuel because sea water is more dense than fuel. If the tank is half filled with sea water and half filled with fuel, the pressure at the bottom will be between the two extremes. The system makes use of this change in pressure brought about by replacing sea water with fuel. The lower reservoir measures this pressure. In accordance with ship practice, the tank is under pressure; therefore, it is necessary to cancel out the effect—this is accomplished by locating an upper reservoir connected to an equalizing line, at the top of the tank, thus making fuel level indication independent of pressure at the top of the tank.

The water filled hydrostatic system for high temperature water tanks, shown in figure 9-10, consists of a remote liquid level indicator, a constant head chamber, a sensing (lower datum) element, connecting piping, and (as an option) a differential pressure transmitter and readout device. When the indicator is installed on a pressurized vessel, a reference head must be provided for comparison with the varying head within the tank. The reference head is provided by the constant head chamber, which has a fill connection and an overflow so that the water level within remains fixed. On a tank vented to the atmosphere, a constant head chamber is not

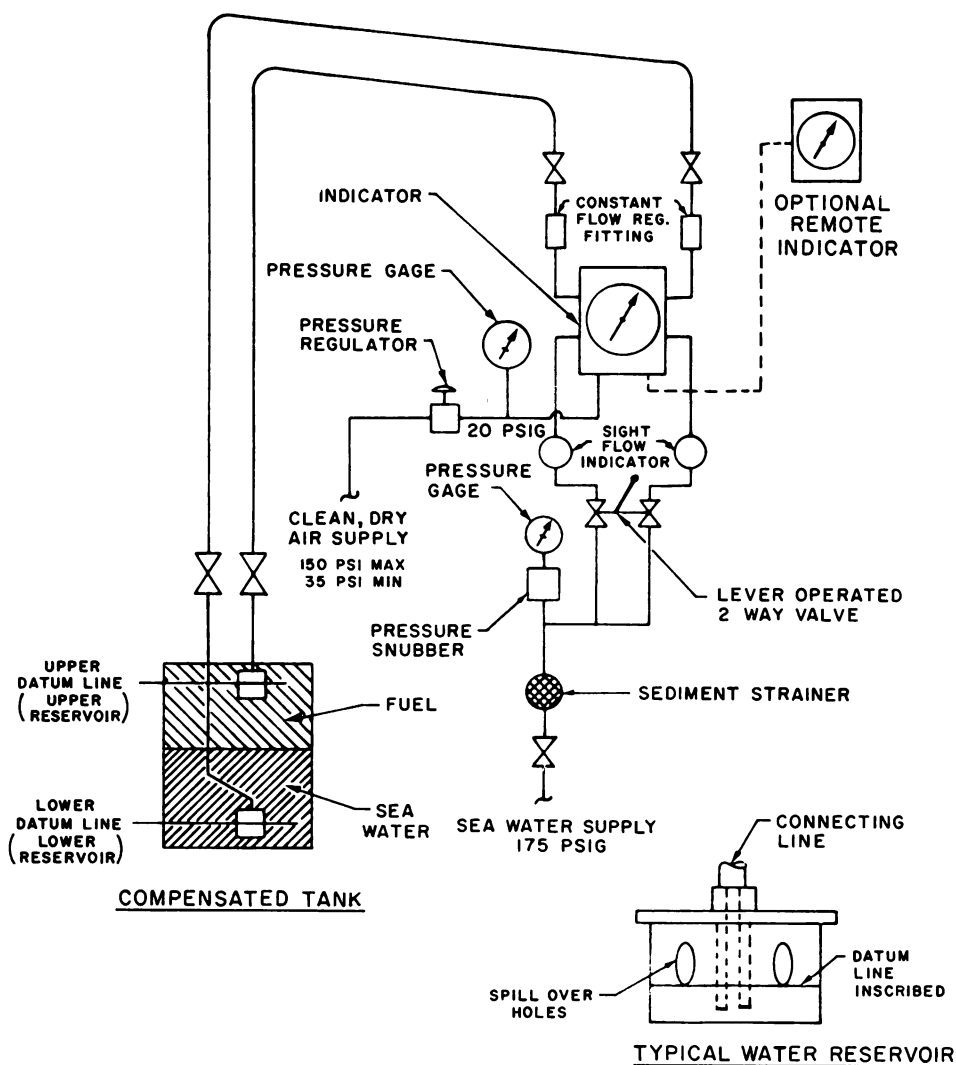


Figure 9-9.—Water filled hydrostatic system for high temperature water tanks.

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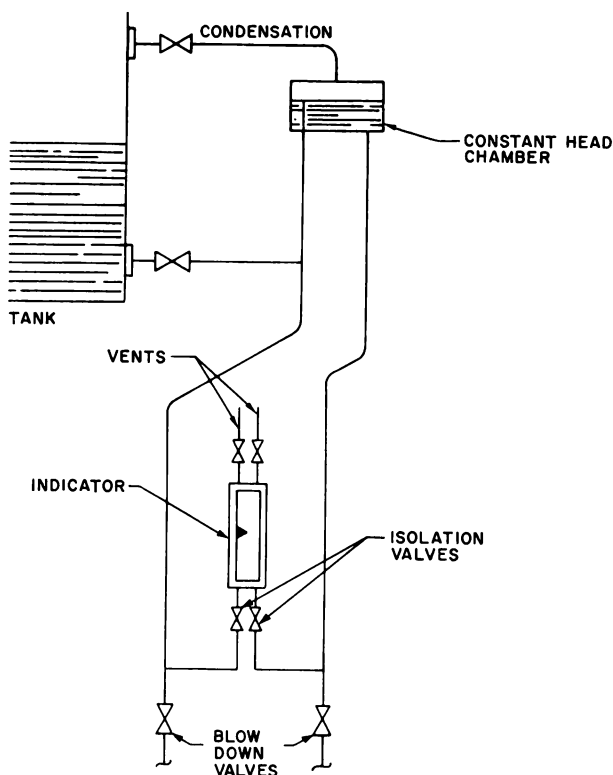
necessary if the instrument can be located at a specified short distance below the bottom of the tank.

The system measures and indicates the difference in pressure between a static and a variable head of water. The static head maintains pressure on one side of the pressure element and the variable head (proportional to water level), maintains pressure on the other side of the pressure element.

To operate the system used for measuring the interface level, first set the air pressure regulator so that the gage pointers reads in the

center of the green operating pressure band. See that all valves between the indicator panel and the tank are open. Pull the level of the purge valve and hold it for at least 30 seconds. Then release the purge valve lever. Level indication can now be read. The level indicator will continue to read the volume of fuel in the tank as long as the air supply is maintained and the system remains open.

To check zero on the indicator, close the panel isolation valves and, with the air on, pull the purge handle. The indicator should read zero. If it does not read zero, one of



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Figure 9-10.—Water filled hydrostatic system for compensated tanks.

the following two procedures can be used.

(1) If a remote indicator is a part of the system, its reading should be checked and if it indicates zero, the transmitting part of the level indicator is functioning satisfactorily. In this instance the pointer should be set on zero. If the remote indicator does not show zero, turn the zero adjustment screw on the panel level indicator. Further zero adjustment should then be achieved by the preceding method mentioned.

(2) If the system has no remote indicator and the zero shift is small (± 20 degrees away from zero), turn the zero adjustment screw on the level indicator until the pointer reads at calibration zero. If the shift exceeds $\pm 20^\circ$, a 0-5 psi gage should be connected to the port labeled "3-15 psig Output Signal to Remote Indicator" and the system "zeroed" as described previously under (1).

The system requires little maintenance—condensate should be drained from the air filter

at regular intervals. Repairs are only accomplished by replacing defective parts or entire components. Detailed information concerning system maintenance and trouble shooting data can be obtained from either chapter 9870 of NavShips Technical Manual or manufacturers' technical manuals for specific equipment.

To place the high temperature water tank level measurement system in operation, it is only necessary to fill the system with pure water, making certain that all air has been removed from the piping and no leaks exist. When the system has been properly filled and vented, additional action is not required to keep the system operating indefinitely, except an occasional blowdown to remove rust and scale from the piping. After venting the constant head side, allow time for the head chamber to fill with condensate (usually about 30 minutes) before taking readings. Never allow steam to enter the indicator; it will damage the diaphragm. If it becomes necessary to drain the tank, shut all isolation valves locking water in the indicating system to prevent having to vent the piping again when returning to operation. If the indicator must be removed, shut the isolation valves on the piping for the same reason. As mentioned previously, maintenance involves only an occasional blowdown of the connection tubes. To disconnect the indicator, perform the following procedure:

1. Secure all electrical power to the unit.
2. Shut all three equalizing valves.
3. Open the vent valves to release pressure.
4. Disconnect the electrical leads.
5. Disconnect tubing at the connector.

The indicator should be disconnected when checking or recalibration is necessary. The equipment required for calibration is a manometer to indicate the inches of water and a means for applying a variable differential pressure. Eliminate all air from the system if water is used to obtain a differential pressure. To check the calibration, establish static differential pressure across the indicator with the pointer positioned successively at each major scale division. Take corresponding manometer readings in inches of water up scale and down, averaging them. Note that the differential pressure does not correspond to the indicator reading directly since an initial differential pressure is required to move the pointer to the high mark. There is also a correction needed for pressure

and temperature variables. Therefore, when correct cold water suppression (initial differential pressure) is applied, the pointer should be at the high graduation mark. If it is not, make a correction with the adjustment screw inside the indicator side cover plate. CAUTION: Do not turn this adjustment screw more than 1/8 turn from the initial position. If the pointer hand is considerably off the high mark, reposition it on the shaft and perform the correction procedure mentioned previously. A range adjustment screw is also located inside the indicator cover plate. One turn of the screw is about 1/8 inch of water per unit of pointer movement. After the range adjustment, repeat the procedure for the high mark adjustment. The technical manuals supplied with the system should be consulted for detailed information concerning the disassembly, maintenance, and calibration procedures.

CLOSED SYSTEMS

Closed systems are primarily used where pneumatic and water filled systems are not suitable for a specific application. Figure 9-11 illustrates closed system hydrostatic level indicators. The use of closed systems is limited to applications where the available differential is adequate for proper functioning of the sensing elements.

In closed system hydrostatic level indicators, the sensing system is liquid filled consisting of a differential pressure element connected by tubing, with diaphragm or bellows type sealed sensing heads at each pressure source (fig. 9-11). Where readout is by dial gage, the scale may be graduated in gallons or pounds of the applicable liquid. Three classes of closed systems are the direct actuated, pneumatic, and electrical systems.

Direct Actuated

In the direct actuated closed system, shown in A of figure 9-11, a dial gage is connected directly to the differential pressure element through a mechanism such as a torque tube assembly. The system is used for applications where the distance from the sensing head to the indicator is 50 feet or less, and where the indicator is located within the tank compartment.

Pneumatic

A pneumatic closed system is shown in B of figure 9-11. Instead of the dial gage of the

direct actuated instrument, a pneumatic transmitter is connected to the differential pressure element. To this, pneumatic receiver and repeater indicators are connected which remotely give a level indication. This system is used for remote indication on surface ships and for applications where hazardous conditions prevent the use of electronic or electrical systems.

The electrical closed system is shown in C of figure 9-11. An electrical or electronic transmitter, suitable for use with remotely located receiver and repeater indicators, is connected to the differential pressure element. System use is for applications on submarines where: (1) venting of air from a transmitter may affect ambient pressure; (2) changes in ambient conditions would affect the indicator calibration; or (3) an electrical signal is required.

The electrical, as well as the pneumatic, system may be used where: (1) the indicator is external to the tank compartment, (2) the distance to the sensing head is greater than 50 feet; or (3) repeater stations are required.

Operation, Maintenance, and Calibration

With the direct actuated system, continuous indication of liquid level is possible immediately upon installation in the tank. With the pneumatic or electrical system, the differential transmitter receives a direct and continuous signal in the same manner as the direct actuated indicator. However, it must be activated pneumatically or electrically to transmit a level indication to the receiver gage.

An accidental high differential will not harm these instruments, however, continuous overloads across the bellows should be avoided.

Under normal operating conditions, the closed systems require no maintenance. Where the sensing heads are accessible, the diaphragms or bellows may be checked occasionally for accumulation of dirt, tar, or other foreign matter. If such accumulations are present, they may be removed with a soft brush and a suitable solvent. DO NOT use a wire brush, knife, or other instrument which might perforate the element.

Since the pressure element-tubing-sensor system is liquid filled and factory sealed, calibration can only be accomplished by applying pressure to the lower (high pressure) sensing element. While calibrating, the upper (low

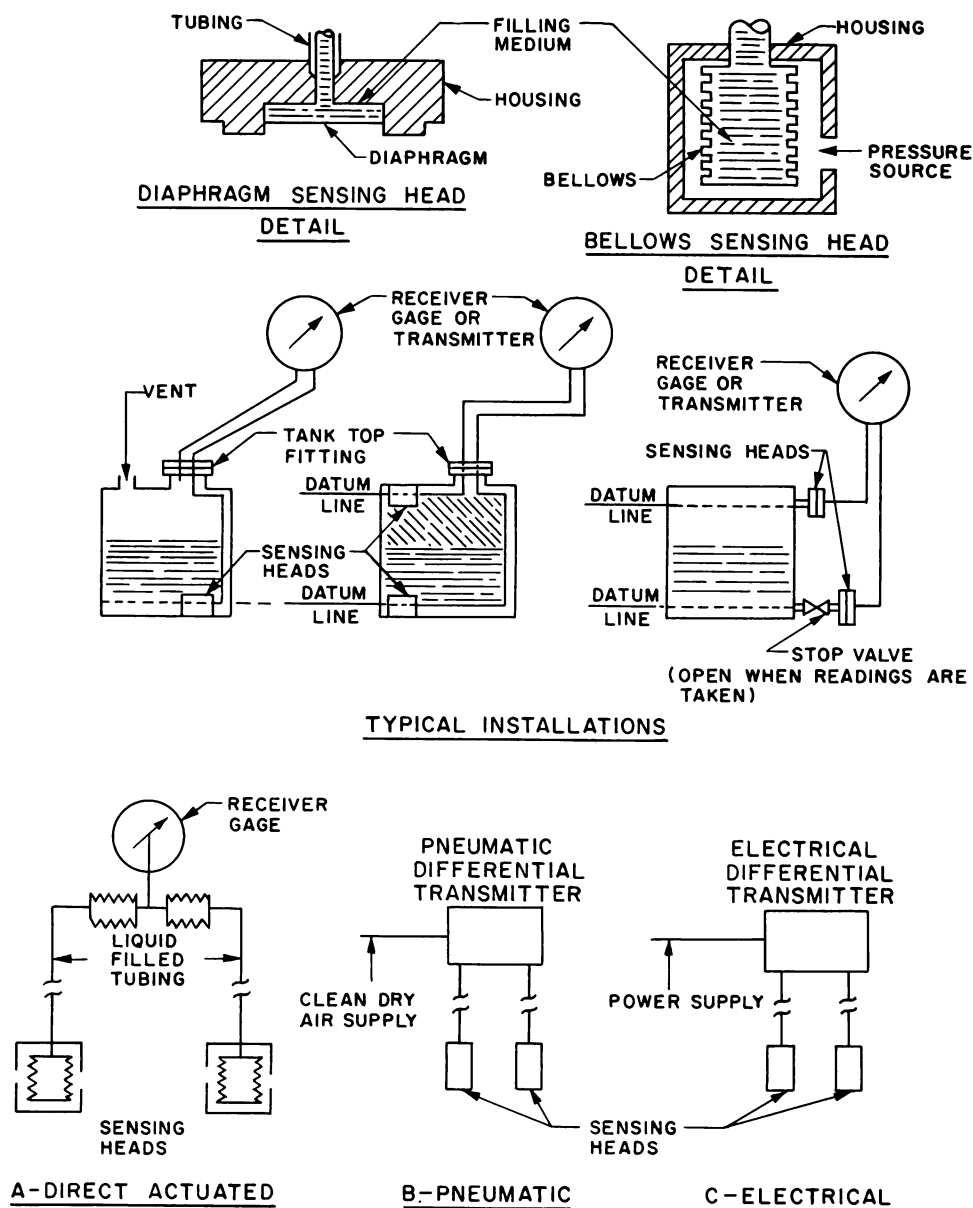


Figure 9-11.—Closed system hydrostatic level indicators.

pressure) sensor should be at atmospheric pressure. Connect the lower sensing element to an air supply that can be measured by a water manometer or other basic standard. See that the sensing chamber is free of liquid when calibrating with air.

For pressurized and open tanks, check zero at atmospheric pressure; for these tanks, zero is obtained when pressure is equalized at the

upper and lower sensors. In this case, the air pressure difference due to the tank height is negligible. Zero is set, as in common pressure gages, roughly by pulling the pointer and finely by a zero adjusting screw. Next, apply a pressure equal to the full differential pressure of the instrument. The pointer should indicate full scale; if it does not, perform a range adjustment. When zero and range are satisfactory, apply a

pressure equal to one half the differential pressure range. If the pointer is off the half scale mark, perform a linearity adjustment. Since the linearity adjustment will affect the overall calibration, repeat the entire sequence until the proper calibration has been achieved.

For compensated tanks, the calibration procedure is similar to that described in the previous paragraphs of this section, except that the zero fuel level is obtained at the maximum pressure differential; in this condition, the tank will be filled with sea water (heavier than fuel). Then full fuel level is obtained at some lower differential pressure equivalent to the head of fuel in the tank.

When pressurizing the pneumatic and electrical systems for calibration, see that their circuits are properly and fully energized. Additional information concerning operation, maintenance, and calibration procedures can be obtained from either NavShips publications or manufacturers' technical manuals for specific systems.

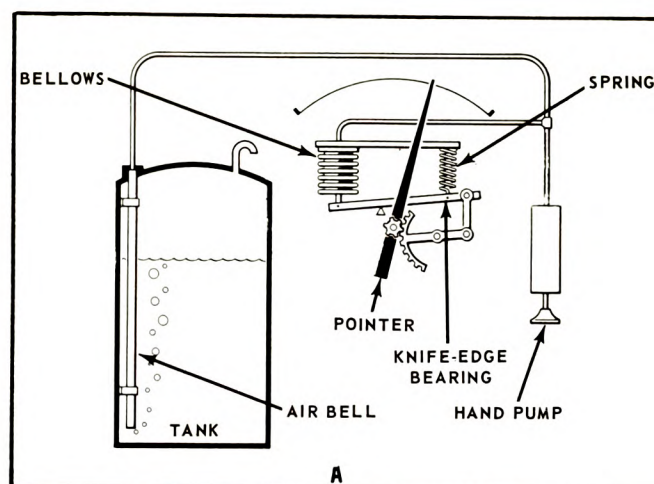
LEVELOMETERS

In order to advance in rate, you must have a knowledge of the procedures for calibrating and adjusting levelometers. Therefore, it is important for you, as an IM3 or IM2, to first understand the principles of operation of levelometers.

A levelometer is a type of hydrostatic gage which operates on an adaptation of the hydrostatic principle. It uses a dial type indicator. Part A of figure 9-12 shows the principle of operation of a levelometer. Part B of this figure shows a gage of a levelometer.

The pipe (air bell) is open at the bottom and connected outside the tank by copper tubing or pipe to the bellows of the indicator (part A, fig. 9-12) and also to the hand pump. The hand pump is used to build up pressure in the air bell equal to the pressure caused by the head of liquid. This pressure, which varies with the head of liquid in the tank, regulates movement of the bellows, which is opposed by a spring. Expansion or contraction of the bellows moves the pointer by means of a linkage system, a sector, and gear. The bellows and spring are positioned at opposite ends of a balance arm which works on a pivot.

For automatic operation of a levelometer, a compressed air supply is essential. Compressed air enters the air bell through one line and a

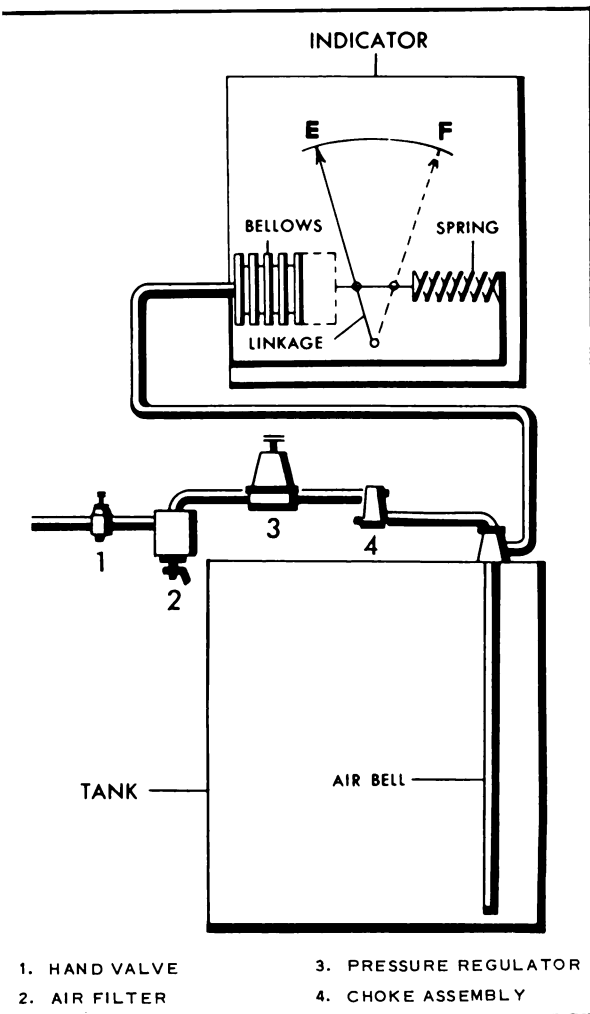


61.7X
Figure 9-12.--A. Principle of operation of a levelometer. B. Levelometer with built-in-hand pump.

separate measuring line is used for registering readings on the gage. Figure 9-13 shows how the lines are connected when a constant supply of compressed air is used.

The choke assembly shown in figure 9-13 contains a corrosion resistant orifice which is further protected by a fine mesh Monel screen. The size of the orifice must be such that it will (1) reduce the flow of air to a value low enough to keep the pressure drop in the air bell negligible, and (2) maintain sufficient air flow through the air bell to produce rapid response of the indicator to changes in the liquid level.

Levelometers employed to measure the contents of tanks under continuous or intermittent pressure must be specially constructed. The

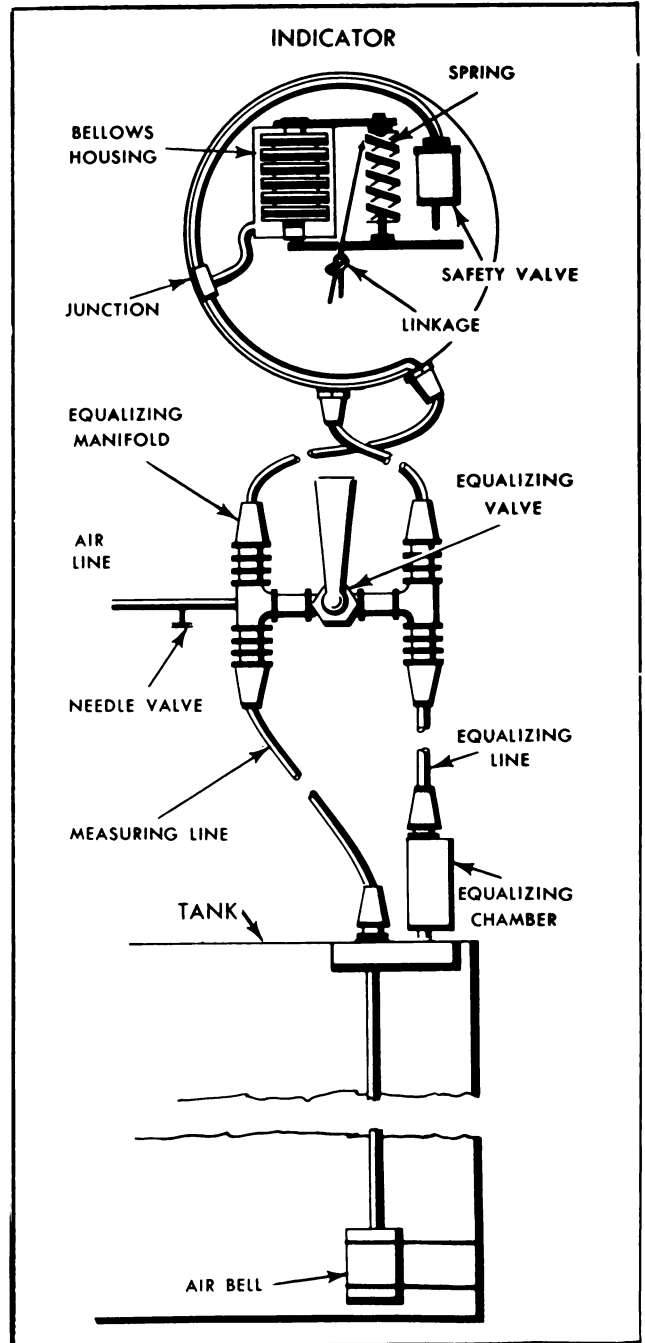


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Figure 9-13.—Levelometer installation for constant air operation.

Indicator case is airtight. Pressure is applied to the outside of the bellows. Such an arrangement is illustrated in figure 9-14.

When a hydrostatic gage is in operation on a pressurized tank, pressure equal to the operating pressure of the tank is transmitted to the inside of the indicator case through an equalizing line (fig. 9-14). The pressure which moves the indicator bellows is equal to the tank pressure, plus the amount of additional pressure required to clear the air bell. Thus, the bellows movement corresponds only to the pressure which results from the head of liquid in the tank.



61.9

Figure 9-14.—Levelometer installation on a tank under pressure.

In the pressure type application of this gage, the air bell is connected to the equalizing manifold by a measuring line and an equalizing line. From the manifold, the equalizing line leads to the inside of the indicator case. The measuring line is connected to a junction (fig 9-14). One line runs from the junction to the bellows housing. The other line from the junction is connected to a safety valve. If excessive pressure is built up in the measuring line, the safety valve opens and permits this pressure to escape into the indicator case and out through the equalizing line. The spring on the balance arm and the linkage to the pointer function in the same manner as those in systems which use a hand pump or compressed air.

The purpose of the equalizing chamber is to equalize the volume of air trapped in the two lines when the pressure is suddenly increased. The equalizing manifold is composed of an equalizing valve (fig. 9-14) connected between

the measuring line and the equalizing line. The air supply is connected to the measuring line side of the manifold through a needle valve, which takes the place of a check valve, used on some hydrostatic gages.

Figure 9-15 illustrates a complete Model 10 levelometer indicator which shows the nomenclature of the parts. This information is helpful in the event that you may be required to repair one of these indicators.

As far as overhaul of hydrostatic liquid level indicators is concerned, overhaul is necessary only if the servicing procedure fails to correct the condition. While the indicator is being overhauled, lines and fittings should be tested in accordance with manufacturer's recommendations for the specific unit.

Overhaul instructions for each indicator include instructions on selecting the correct spring. The same procedure is followed when it is necessary to change the spring in order to

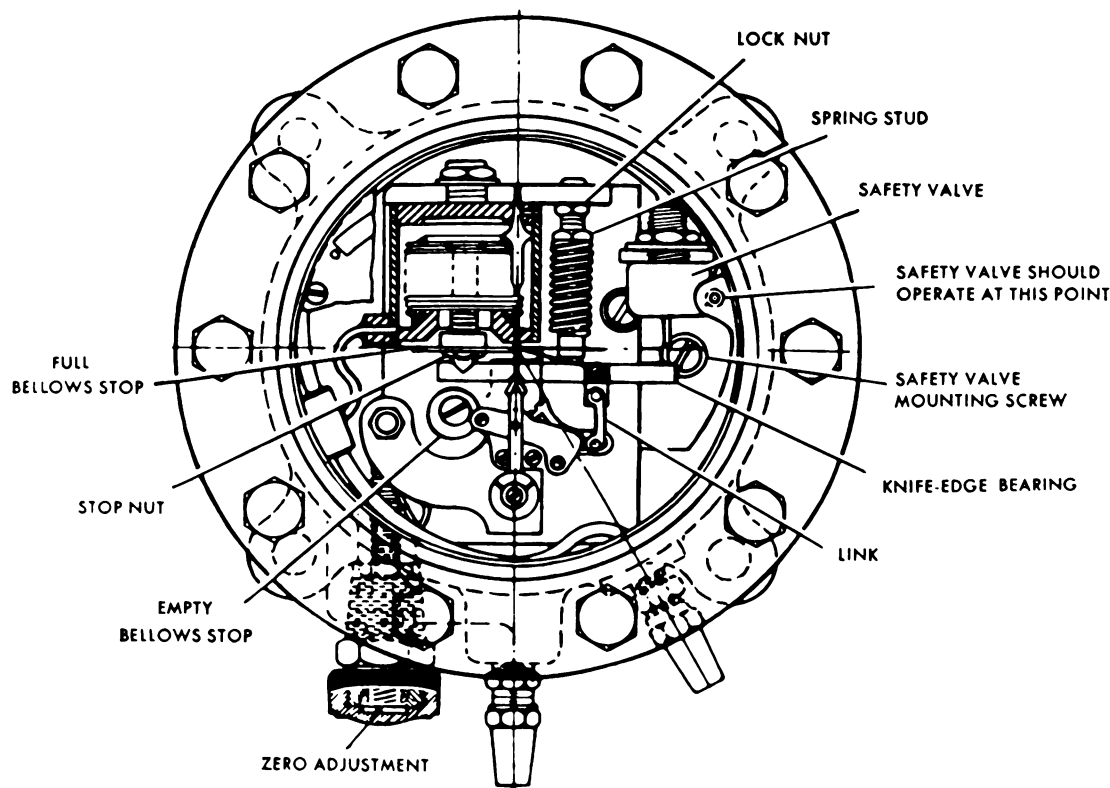


Figure 9-15.—Model 10 indicator.

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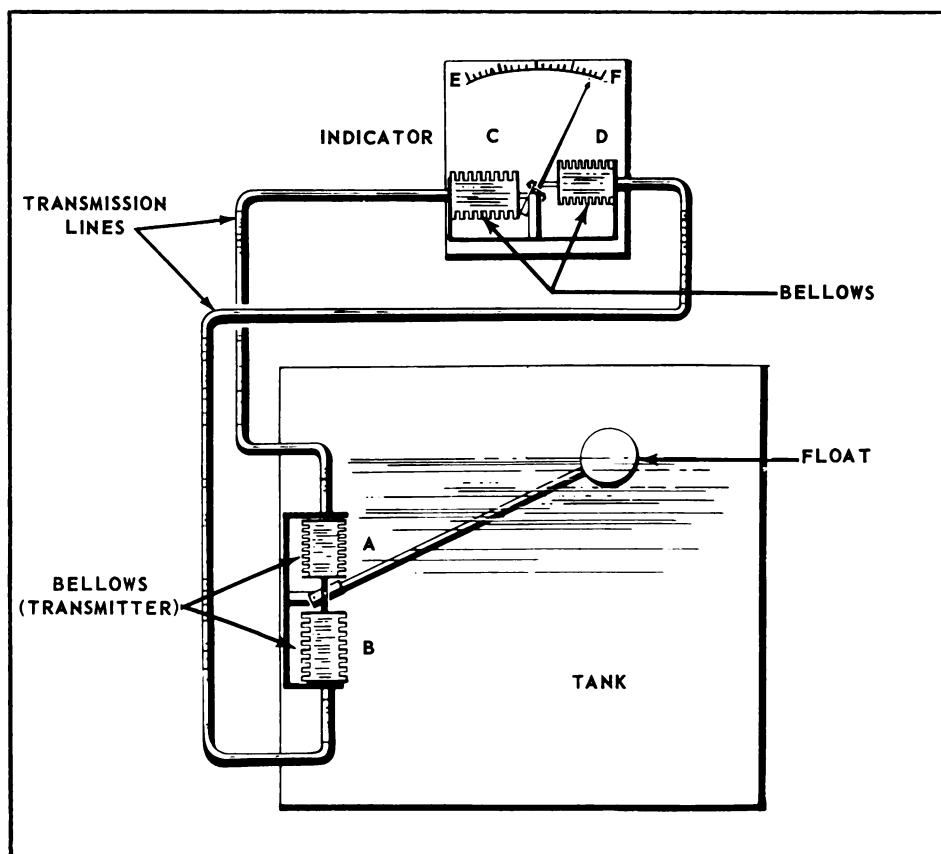


Figure 9-16.—Hydraulic level indicating system with transmitter inside the tank.

61.10

adapt the indicator mechanism to a specified tank height; in this case, the indicator need be disassembled only sufficiently to replace the spring. (NOTE: Wherever soldering is required, use 50-50 solder and noncorrosive flux.)

Detailed information concerning the overhaul of Model 10-1 and 10-2 (pressure-type marine) indicators can be obtained from the instruction book Tank Capacity Gauges Liquidometers and Levelometers, NavShips 387-0276.

As far as preliminary inspection and testing of indicators is concerned, the inside of the housing should be inspected for evidences of tank contents having been forced into the housing. A leak in the measuring line can cause the tank contents to be forced up through the equalizing line into the housing; a leak in the equalizing line can cause tank contents to be forced up the

measuring line into the bellows, and then out through the safety valve into the housing.

If tank contents have entered the housing, all parts should be carefully checked for corrosion or damage. Provide tubing and fittings by means of which compressed air can be applied from a common source to the indicator's measuring line and equalizing line fittings while the indicator is immersed in water. Immerse indicator in water. Apply pressure (300 psi to Model 10-1 or 500 psi to Model 10-2) and watch for bubbles indicating leaks in the housing, around the zero adjustment, fittings, and lens.

To clean the unit, air-blow parts to remove foreign matter. As for lubrication, none is required. Additional information concerning the operation, overhaul, maintenance, and adjustment of levelometers can be obtained

from manufacturer's instruction books for specific equipment.

FLOAT ACTUATED (HYDRAULIC) REMOTE READING LIQUID LEVEL INDICATORS

A hydraulic type level indicator (liquidometer) employs a float-actuated hydraulic system to indicate on a remote-reading gage the amount of liquid in a tank. As shown in figure 9-16, the system consists of three components: (1) the float assembly, (2) the transmitter, and (3) the indicator. Remote-reading hydraulic gages are completely automatic and self-contained. Liquid level is instantaneously indicated on the gage dial. The transmitter may be either an integral part of the tank linkage, or a separate detachable part (fig. 9-17).

Power for operating a hydraulic gage is derived from a float and arm movement (fig. 9-16). Bellows A and B in the tank unit (fig. 9-16 and fig. 9-17) are fixed at their outer ends and linked together at their inner ends. Bellows C and D in the indicator are also arranged similarly. Both sets of bellows are connected by copper transmission tubing. The tubing and bellows are filled with fluid (kerosene) and sealed at the factory. (NOTE: The transmission tubing consists of two capillary

tubes encased in rigid conduit for the major portion of the system with flexible pieces at the end for ease of connection.)

When the float moves down because of a lower liquid level in the tank, bellows B compresses and displaces a portion of the liquid from it. The increased pressure in the line from bellows B causes bellows D to expand. Simultaneously, bellows A expands, taking in liquid displaced from bellows C, and causing bellows C to compress. When the float rises as a result of an increase in the amount of liquid in the tank, the bellows action just explained is reversed. As bellows C and D expand and compress, respectively, the gage linkage system is activated, driving the pointer, which moves between E (Empty) and F (Full) on the gage scale. When the amount of liquid in the tank is increased, this movement is in the reverse direction and the pointer moves toward F (full) on the scale.

Study figure 9-17, which shows all the different parts of a hydraulic tank level indicator with the tank unit on top of the tank, and the transmitter outside the tank.

Multiple float and transmitter arrangements may be used where tank depths exceed the practicable limit for single float operation. The float rises as the tank is being filled and moves the pointer on the dial until the float

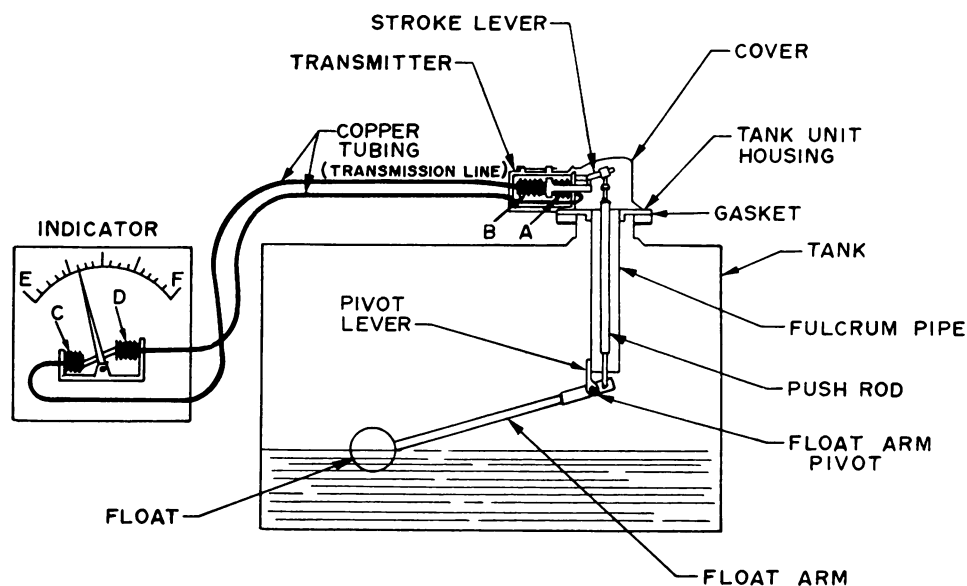


Figure 9-17.—Hydraulic level indicating system with transmitter outside the tank.

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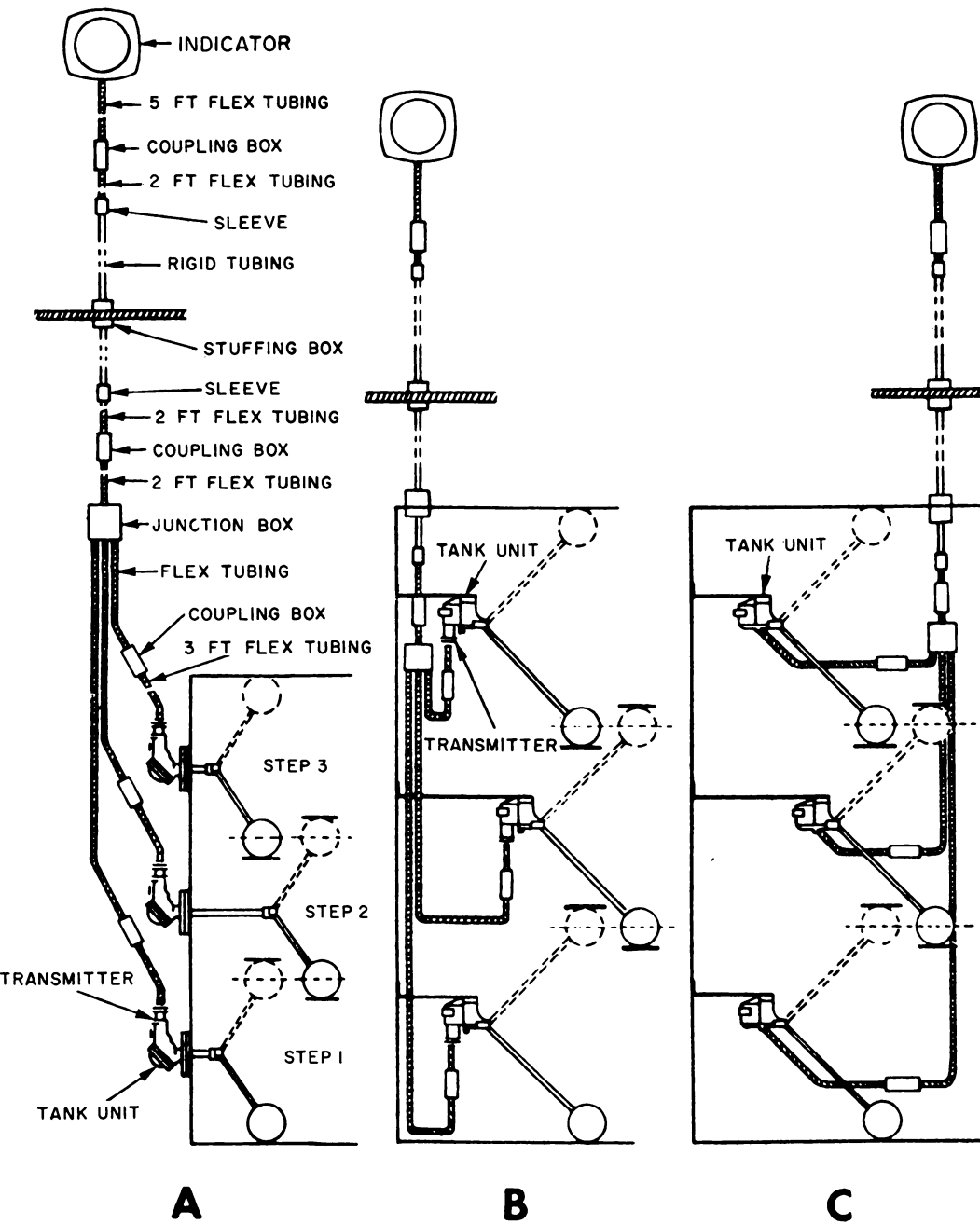


Figure 9-18.—Typical multiple-step applications.

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reaches its upper limit of travel. As the liquid level increases beyond the limit of the first float, the second and subsequent floats, rising with the increased liquid level, cause the pointer to continue its operation.

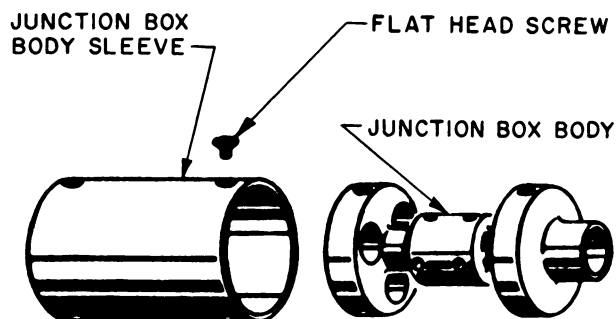
Hydraulic gages can be used on compensated tanks—tanks which contain two liquids of different specific gravities, such as gasoline and sea water. In this case, the float or floats are weighted so that they sink through the top liquid, and float on the interface, or cleavage line.

Since the operation of the hydraulic liquid level indicator is completely automatic, it is merely necessary to observe the dial to obtain a capacity reading. Because the system is actuated by a float, true volumetric indication may be obtained at all times, regardless of changes in specific gravity of the liquid or pressure within the tank.

UNIT COMPONENTS AND APPLICATIONS

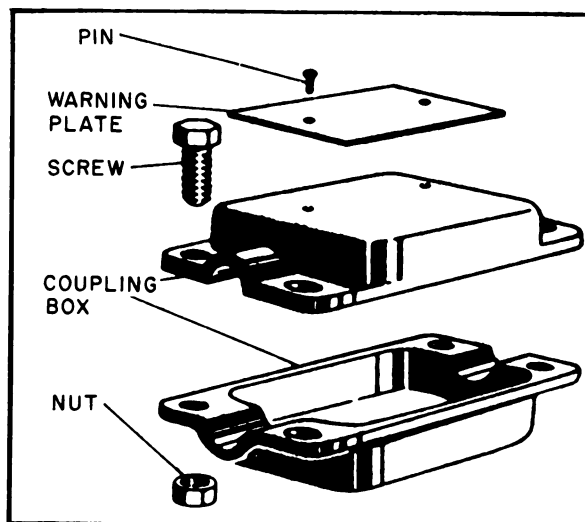
Figure 9-18 illustrates a typical multiple-step unit with all components; A shows the external mount tank units, B and C show the internal mount tank units. The line components are the same in all systems except for the tank units. Note that the float stops are so located that the centerline of one float at its upper limit of travel corresponds with the centerline of the next higher float at its lower limit. Float arm guides are installed whenever the float arm radius exceeds 30 inches.

As with single-step applications, each transmitter is equipped with 3 feet of flexible transmission tubing terminating in a coupling box. From the coupling boxes, additional lengths of flexible tubing, as required, run to a junction



61.183

Figure 9-19.—Junction box assembly.



61.18

Figure 9-20.—Line coupling box assembly.

box, which is provided with 2 feet of flexible tubing and a coupling box for connection to the main transmission tubing. On internal mount installations, a stuffing box is provided at the point where the main transmission line emerges from the tank.

Figure 9-19 illustrates a disassembled junction box and figure 9-20 shows a disassembled line coupling box. Figure 9-21 illustrates the assembled junction box on the right hand side of the drawing and how it is attached to the bulkhead. Figure 9-21, also illustrates the assembled line coupling box and how it is mounted to the bulkhead. Figure 9-22 shows how the transmission tubing between the tank units and the junction box should be secured to the bulkhead to help protect the units.

An exploded view of a hydraulic indicator is shown in figure 9-23. An illustration (exploded view) of a tank unit is shown in figure 9-24. Additional information concerning parts and functions of these units can be obtained from Tank Capacity Gauges Liquidometers and Levelometers, NavShips 387-0276 or manufacturers' technical manuals for specific equipment.

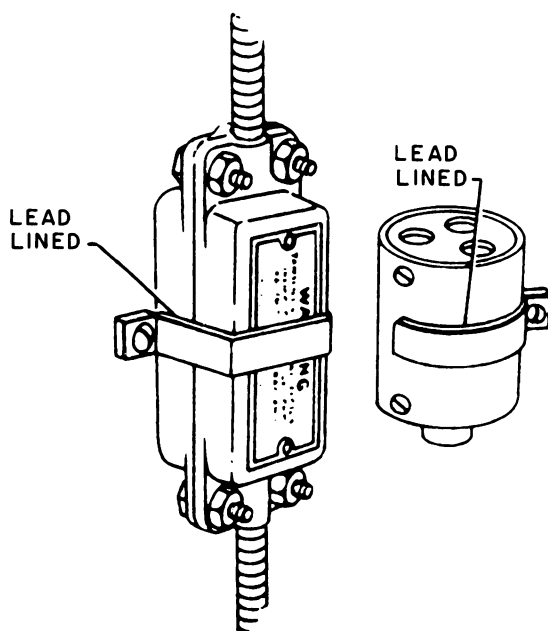
MAINTENANCE AND CARE

When trouble is evident in a hydraulic level indicator all parts of the instrument usually must be checked. There may be a leak in the

tubing, a defective bellows, or a binding in bearings or bearing pins linking the float and transmitter movements.

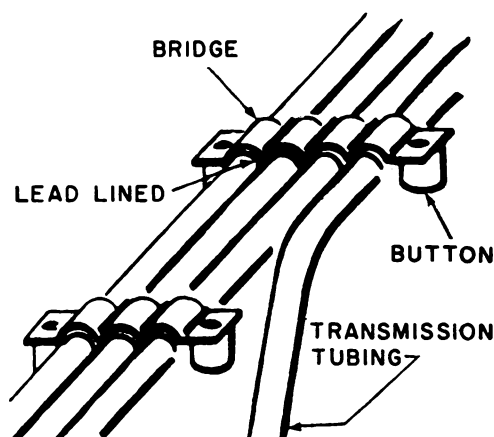
In diagnosing the trouble, first tighten all fittings, then check the entire system, and re-fill it with a filling set. Complete instructions for making these tests and using the filling set may be found in service manuals supplied by manufacturers of the system.

If unsatisfactory operation is found to be caused from binding in bearings or bearing pins of the float-transmitter linkage, it can usually be eliminated by checking adjustments and providing freedom of operating at each connection. When all linkages have been freed



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Figure 9-21.—Typical bridge straps for coupling box and junction box.



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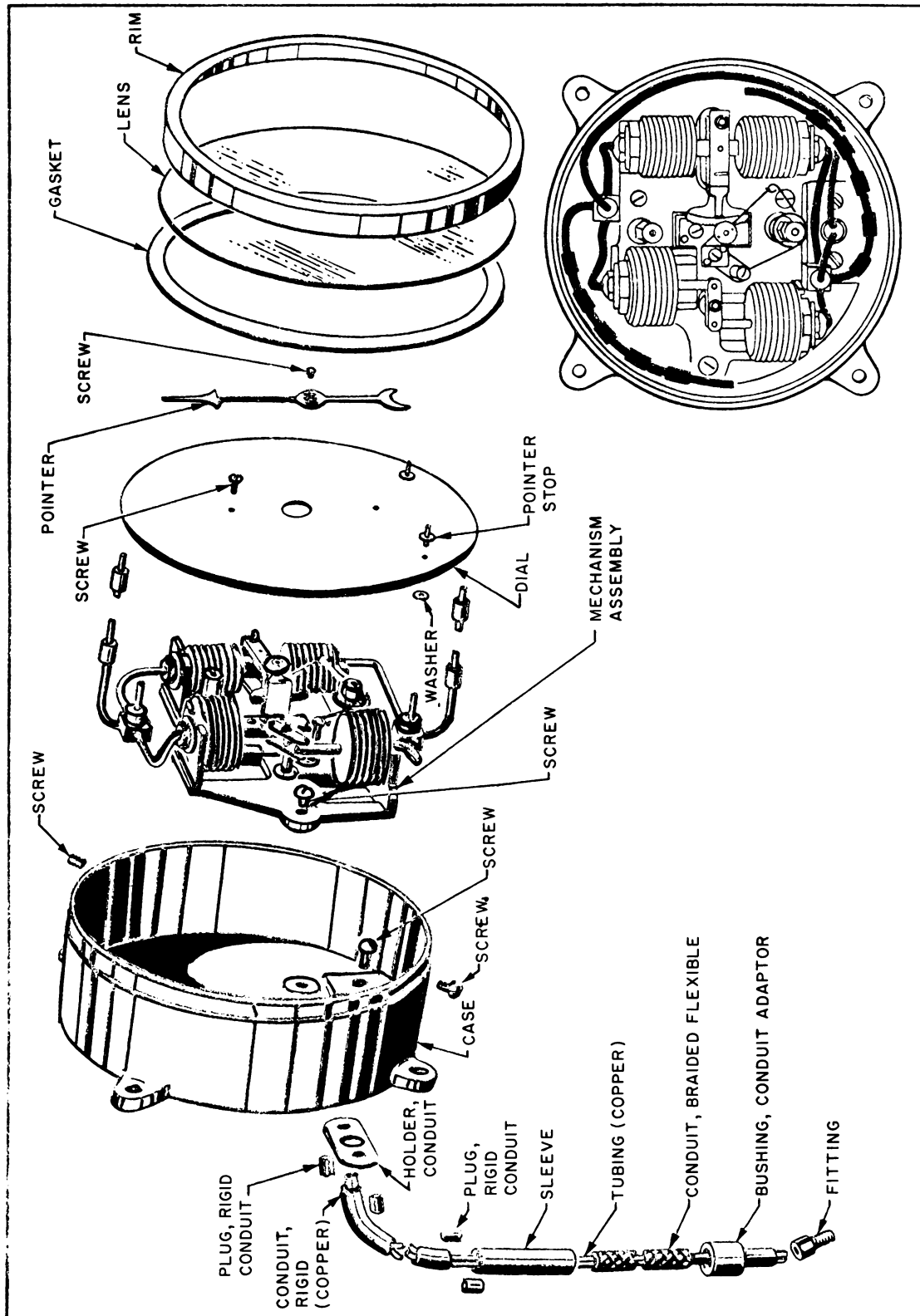
Figure 9-22.—Bridge straps for transmission tubing.

and the pointer moves from EMPTY to FULL on the dial as the float is moved from the bottom to the top of the tank, the instrument is satisfactory.

If the instrument still fails to operate after linkages have been freed then it must be checked for leaks in accordance with manufacturer's instructions for the specific unit.

All service and repairs on these instruments should be performed by qualified instrumentmen.

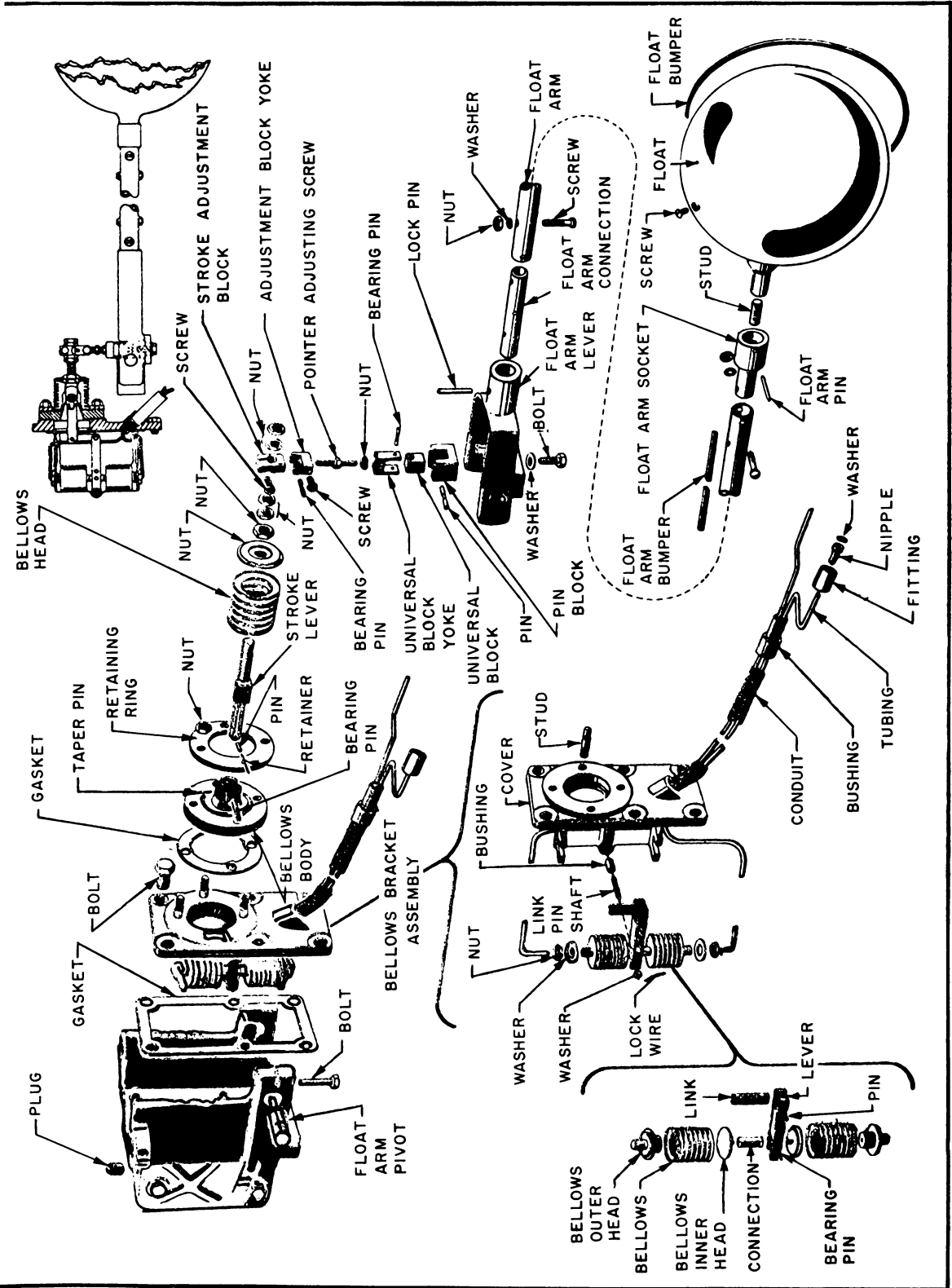
Information dealing with adjustment or calibration of hydraulic liquid level indicators, or liquidometers, can be obtained from Instrumentman 1 & C, NavPers 10194-B. Additional information concerning maintenance and calibration of liquidometers, can be obtained from manufacturer's technical manuals.



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Figure 9-23. —Hydraulic indicator.

Figure 9-24. —Internal mount oil-filled tank unit.



CHAPTER 10

FLOW INDICATORS

Many boilers—particularly double-furnace boilers—are equipped with steam flow indicators. In order to understand the operating principles of steam flow indicators as a basis for the repair and calibration of these units, required for advancement to IM 1, the Yarway and Jerguson indicators are covered in this chapter.

Fluid flow meters, however, are used aboard ship to measure the amount of fluid that flows past a given point at any given instant (rate of flow) and the amount of fluid that flows past a given point during a definite period of time (total flow). The total flow meters described in this chapter are positive displacement meters and velocity meters. Rate of flow meters described are venturi meters, area meters, and magnetic flow meters.

The physical properties of fluids important in flow metering, especially when calibrating a flow meter, are pressure, specific weight or density, temperature, viscosity, and velocity. Pressure, as defined earlier in this manual, is force per unit area, expressed in pounds per square inch (psi). Density is the weight per unit volume of a substance, usually expressed in pounds per cubic foot. Changes in temperature of a fluid affect the pressure and density, or specific weight. An increase in temperature causes an increase in pressure but a decrease in density.

Viscosity is the internal resistance of a fluid which tends to prevent it from flowing. No two fluids will have the same viscosity; for example—Molasses compared with water. Viscosity is expressed in pound—seconds per square foot in the English system, and known as ABSOLUTE VISCOSITY. Absolute viscosity divided by fluid density is known as KINEMATIC VISCOSITY. In most tables viscosities are expressed in metric units: centipoise for absolute viscosity and centistokes for kinematic viscosity. These converted by the following relations:

$$\begin{aligned} 1 \text{ lb-sec/ft}^2 &= .672 \text{ centipoise (absolute viscosity)} \\ 1 \text{ ft}^2/\text{sec} &= .01076 \text{ centistokes (kinematic viscosity)} \end{aligned}$$

Viscosity is also expressed in units by which it is measured with a viscosimeter, such as the Saybolt Universal, giving viscosities in Saybolt Seconds Universal (SSU). Temperature changes also affect viscosity; for liquids, an increase in temperature decreases viscosity and for gases, an increase in temperature increases viscosity.

Velocity of a flowing fluid, usually measured in feet per second, is its speed in the direction of flow. In flow metering, it is important because it determines the behavior of the fluid. When average velocity is low, flow is said to be laminar. This means that the fluid flows in layers with the fastest moving layers towards the center and the slowest moving layers at the outer edge of the stream. (An example is an open stream flowing at a slow uniform rate with logs floating on its surface. The logs represent particles of fluid. As long as the stream flows along at a slow uniform rate, each log floats downstream in its own separate path without crossing or bumping into the other.)

As the velocity increases, the flow becomes turbulent: the layers (laminability) disappear and velocity across the stream, mentioned earlier, becomes more uniform. For example, if the stream narrows and the volume of flow remains the same, the velocity of flow increases. If the volume increases sufficiently, the water becomes turbulent. Swirls, eddies, and cross-motions are set up in the water. As this action occurs, the logs are thrown against each other and against the banks of the stream, and paths followed by different logs will cross and recross.

In pipes, particles of fluid flowing therein act as mentioned in the previous paragraph. The flow is streamlined if the fluid flows slowly

remains streamlined at greater than the pipe diameter is small. If the velocity of flow or the size of the pipe is insufficiently, the flow becomes turbulent. High velocity of flow will produce turbulence in any pipe, other factors which contribute to turbulence are: roughness of the pipe, size and degree of curvation of bends, number of bends in the pipe. Generally all shipboard systems, flow is determined only the average velocity of a cross section of the stream is constant:

$$\text{velocity} = \frac{\text{rate of flow}}{\text{area of pipe}}$$

In metering, the nature of flow can be determined by a number—the Reynolds Number,

$$\text{Reynolds Number} = \frac{\text{Average velocity} \times \text{density} \times \text{internal diameter of pipe}}{\text{absolute viscosity}}$$

$$\text{Reynolds Number} = \frac{\text{Average velocity} \times \text{internal diameter of the pipe}}{\text{kinematic viscosity}}$$

Reynolds Number, it can be determined whether the flow is laminar or turbulent. If the Number is less than 2000, the flow is laminar; if the Number is greater than 2000, the flow is turbulent. Between these values there is a transition zone where the flow is unpredictable.

SUPERHEATER STEAM FLOW INDICATORS

Superheater steam flow indicators measure the pressure differential between the superheater inlet and the superheater outlet. Since the pressure drop across the superheater is proportional to the rate of steam flow through the superheater, the pressure drop can be used to determine the rate of steam flow. Superheater steam flow indicators are usually calibrated in inches of water, since they measure small pressure differential. (NOTE: In double-furnace boilers, the steam flow indicator is usually set at two inches as the minimum. In other words, fires should not be so hot that the superheated side of double-furnace boiler has reached the two-inch mark, which is an indication of sufficient flow of steam.)

Where installed, superheater steam flow indicators must be kept in good operating condition at all times. The superheater outlet thermometers indicate temperature at the superheater outlet, not inside the superheater; and, on a double-furnace boiler, generally equipped with such indicators, it is possible to have no flow through the superheater while the thermometers are giving perfectly normal readings at the outlet. In other words, there is no way to be sure a superheater is not being overheated unless both the superheater outlet thermometers and the superheater steam flow indicator are in good working condition.

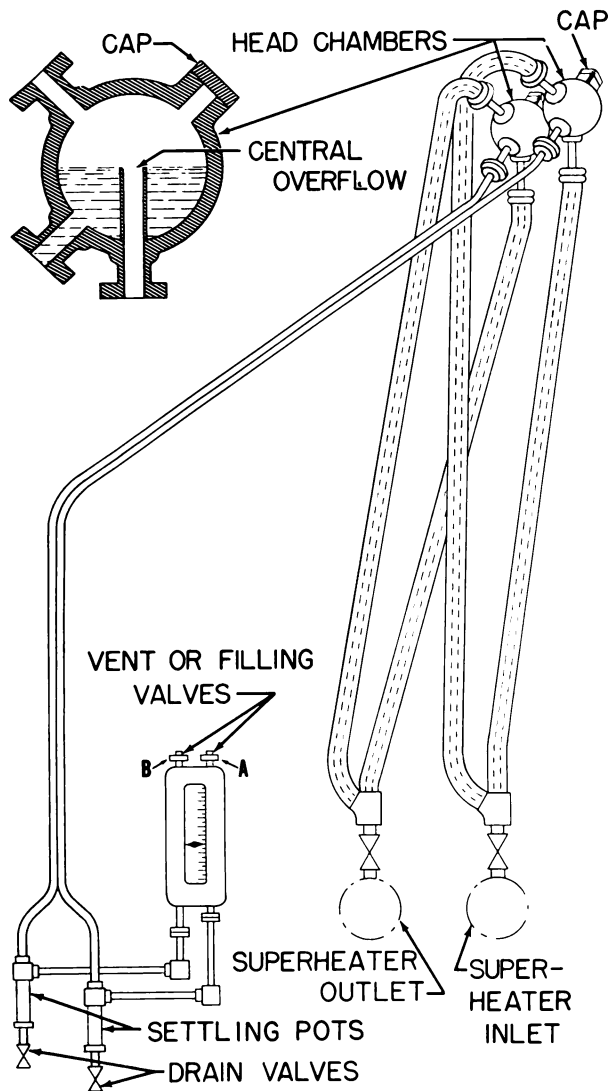
Two types of superheater steam flow indicators (Yarway and Jerguson) are in common naval use. Although both respond to the pressure differential between the superheater inlet and the superheater outlet (and are calibrated to read inches of water), they differ in the mechanism by which this pressure difference is measured and transmitted to an indicating dial.

YARWAY SUPERHEATER STEAM FLOW INDICATOR

The Yarway superheater steam flow indicator responds to the difference between superheater inlet pressure and superheater outlet pressure as these two pressures act upon separate columns or heads of water. The general arrangement of the Yarway superheater steam flow indicator is shown in figure 10-1.

A constant water level is maintained in the two head chambers (reservoirs). Both head chambers are in one casting, but the upper head chamber is located slightly above the lower head chamber in order to provide a slight constant pressure differential which serves to stabilize the zero reading. Steam from the superheater inlet is led to the upper head chamber, and steam from the superheater outlet is led to the lower head chamber. Exposed piping connects each head chamber with the indicating unit.

The interior of the indicating unit is shown in figures 10-2 and 10-3. As may be seen, the water from the upper head chamber enters the indicating unit on one side of the diaphragm, and the water from the lower head chamber enters on the other side. The pressure from the upper head chamber is greater than the pressure from the lower head chamber, so the diaphragm is moved accordingly. The diaphragm is connected

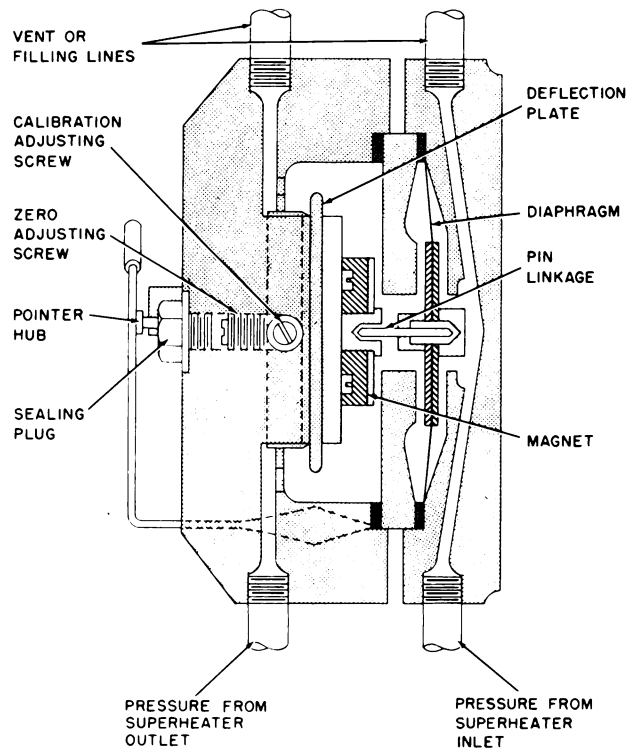


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Figure 10-1.—General arrangement of Yarway superheater steam flow indicator.

by a pin linkage to a deflection plate which moves in sensitive response to the movement of the diaphragm.

A permanent horseshoe magnet is rigidly mounted on that side of the deflection plate which is free to move. The poles of the magnet straddle a tubular well in which a spiral-shaped strip armature is mounted on jeweled bearings. A counterbalanced pointer is attached to the end of the armature mounting shaft.

When the deflection plate moves in response to variations in pressure, the magnet is made to move along the axis of the well. As the magnet



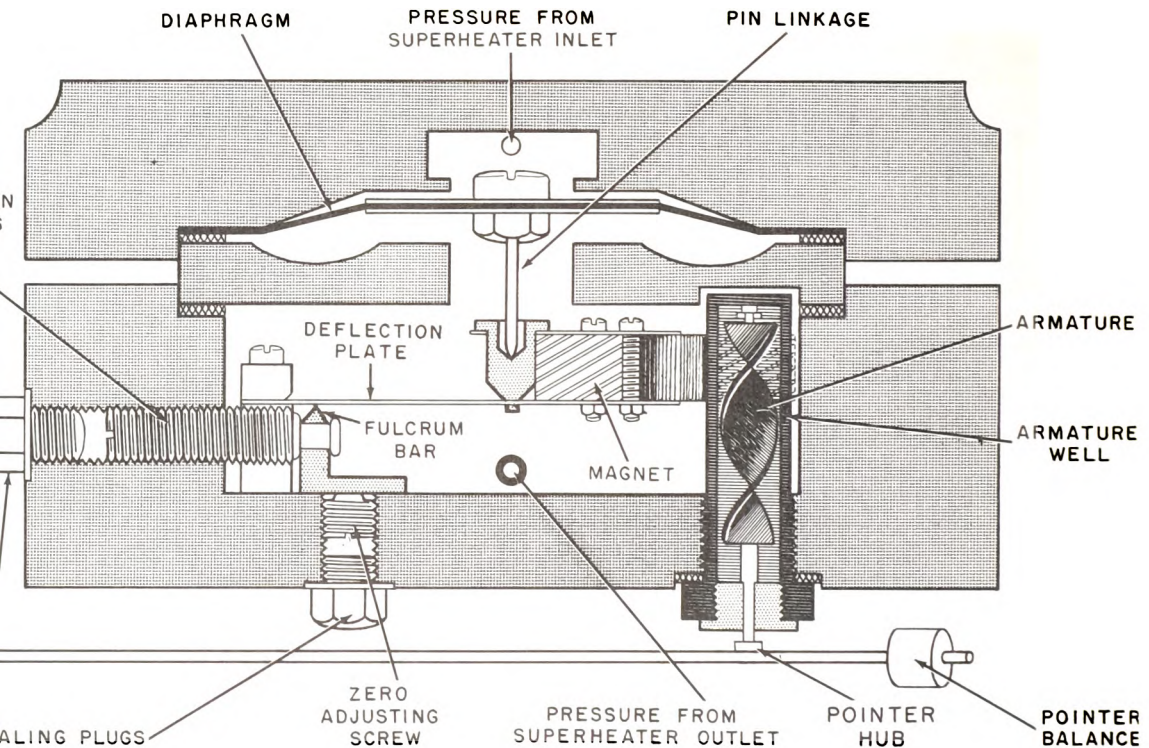
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Figure 10-2.—Cross section of Yarway indicating unit (front view).

moves, the spiral-shaped armature rolls in order to keep in alignment with the magnetic field between the poles of the magnet. Thus a rotary motion is imparted to the armature mounting shaft; and the rotation of the shaft causes the pointer to move. The pointer hand moves over a brightly illuminated vertical dial which is divided into green and red zones to represent safe and unsafe operating conditions.

Information concerning maintenance and calibration of steam flow indicators can be obtained from either NavShips publications or manufacturers' technical manuals for specific equipment.

JERGUSON SUPERHEATER STEAM FLOW INDICATOR

The Jerguson superheater steam flow indicator, shown schematically in figure 10-4, consists of three main parts: (1) a datum chamber assembly, (2) a valve manifold, and (3) an indicating unit.



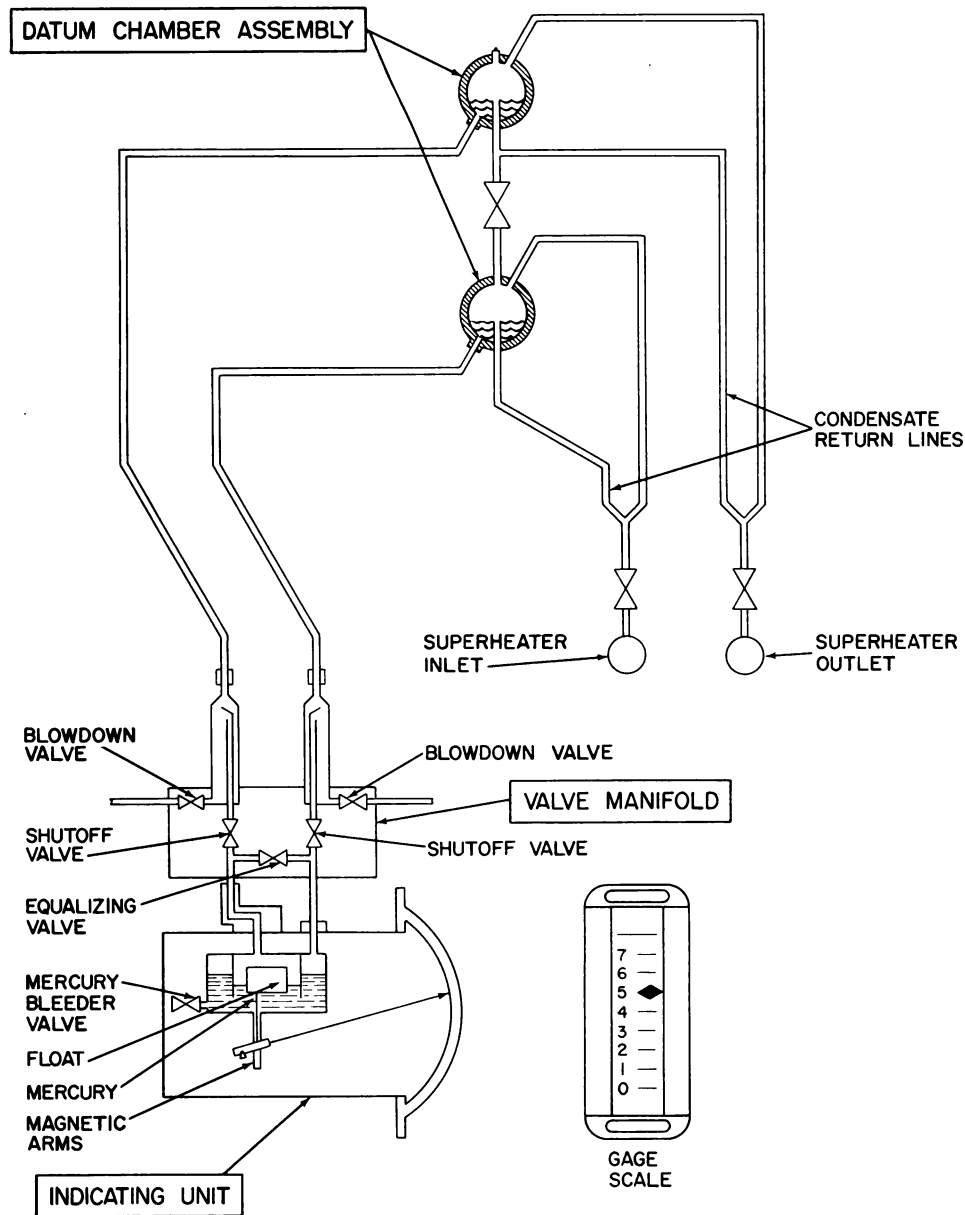
98.92

Figure 10-3.—Cross section of Yarway indicating unit (plan view).

Ferguson indicator is essentially a mercurial manometer with a stainless steel float on one leg. As the pressure differential between the superheater inlet and the superheater outlet varies, the mercury level in the float changes and thereby actuates the pointer. The movement of the float manometer is transmitted to the pointer scale by means of a magnetic coupling. The coupling consists of an internal armature on the end of the float shaft and an external yoke with magnetically energized poles, forming a part of the pointer mechanism. The yoke pivots on precision bearings in order to remain in alignment with the internal armature as the float shaft moves up and down. The armature moves up and down. The float chamber is connected by piping to the superheater inlet and outlet connections and provides the means for impressing pressure on the instrument. As previously, the pressure difference between superheater inlet and superheater outlet is a measure of the rate of steam flow through the superheater.

The indicator is calibrated at the factory so that the pointer position may be read directly in inches of water. When putting the instrument into service, or when replacing mercury after repairs have been made to the unit, pour 5 pounds of mercury into the indicator through the filling connections. This amount of mercury is somewhat in excess of that actually required for the operation of the indicator, but the excess mercury is required for accurate calibration of the instrument. The excess (approximately 1/4 pound) is drawn off through the bleeder valve as the indicator is being adjusted. When there is no pressure on the instrument, the amount of mercury should be adjusted until the pointer comes to the top line on the scale (the 8-inch mark). The mercury that is drawn off through the bleeder valve should be recovered and saved for future use.

After the proper amount of mercury has been added (as indicated by the position of the pointer on the top line of the scale) add clear tap water to both connections until the indicator unit is full. Then install the valve manifold over the indicator unit. Install 3/8-inch piping from the



98.96

Figure 10-4.—Jerguson superheater steam flow indicator.

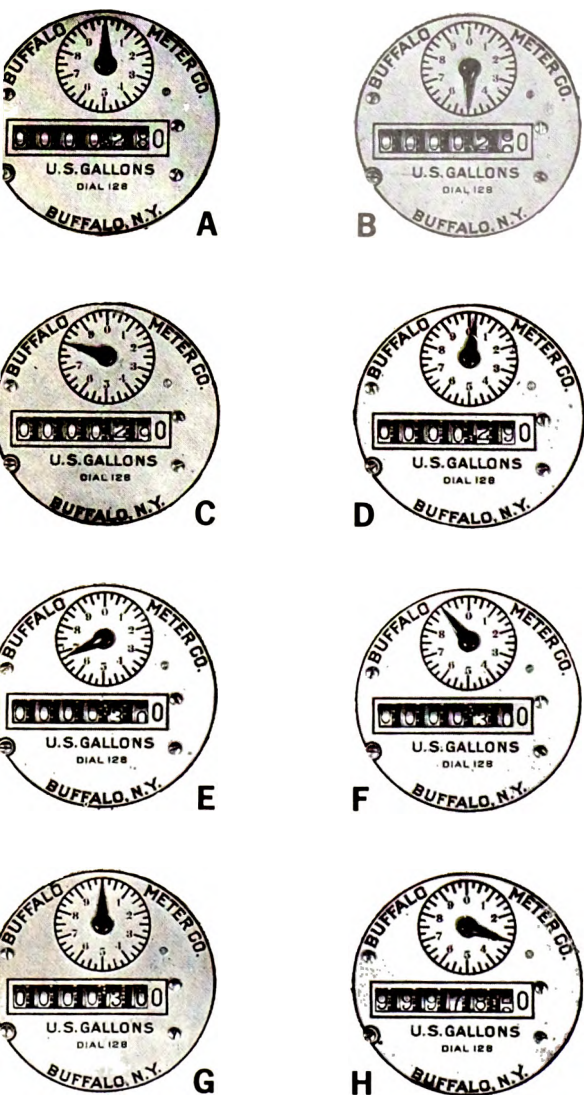
valve manifold blowdown outlets, making sure that the pipes terminate in suitable locations. Install 1/2-inch OD tubing between the valve manifold and the datum chamber. The datum chamber should be mounted vertically at some convenient location above the superheater connections, and the inlet and outlet connections should be made as shown in figure 10-4.

FLUID FLOW METERS

Fluid meters are used on board ship to measure the flow rate of fuel oil, diesel oil, water, gasoline, and other liquids. Accurate measurement of the rate of flow of a liquid through a meter is not meaningful unless the recorded amount is correctly read. Some different types

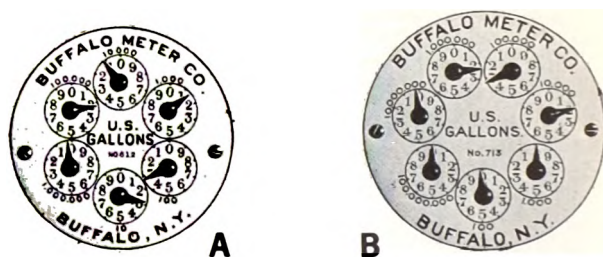
of dials used on fluid meters are shown in figures 10-5 and 10-6. The dial readings are generally in U.S. gallons unless otherwise specified on the dial face. The dial faces shown in figure 10-5 are for the straight reading type meter; the dial faces shown in figure 10-6 are for a round reading meter.

To read the straight reading meter, read from left to right and add the number indicated by the small pointer above. For example in part A of figure 10-5 the reading is 0000280. Part B shows the reading to be 0000285. As the pointer turns, so does the right-hand, numbered



61.13X

Figure 10-5.—Straight reading registers.



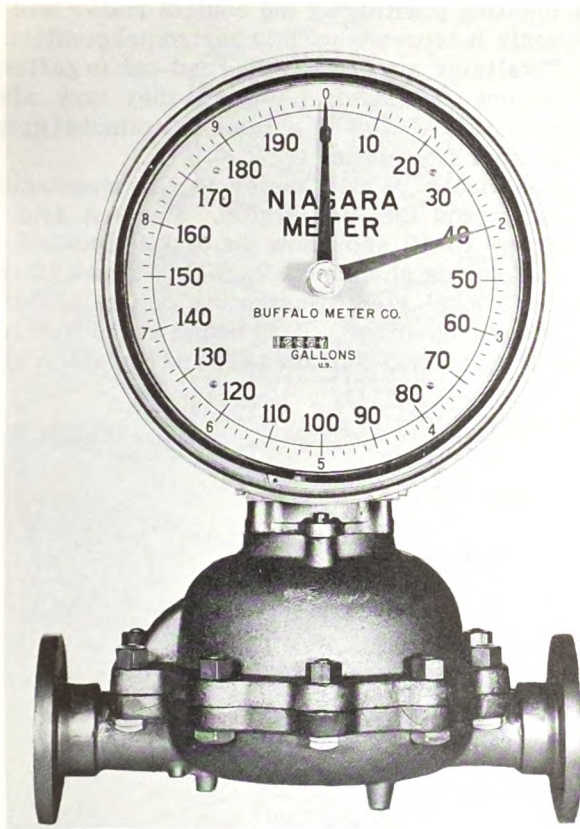
61.13X

Figure 10-6.—Round reading registers.

roller. Even though the next higher number is partly exposed always read the lesser number, which is the number disappearing from sight. When the small pointer is at 0 all the numbers in the straight reading dial will be centrally aligned, as shown in part A and part G of figure 10-5. When the small pointer is at 8 or 9 (part C of fig. 10-5), the next larger number on the numbered roller is almost completely exposed, but the lesser number must be read. The dial in part C of figure 10-5 reads 288 gallons, not 298 gallons.

To read the round reading dial face (fig. 10-6), take the lesser number of the two between which the hand points in each circle. Notice that each circle indicates tens, hundreds, thousands, tens of thousands, etc. Place the number taken from the circle marked "tens" in the units position, place the number taken from the circle marked "hundreds" in the tens place; and continue similarly for the remaining circles. Each division of any circle stands for one-tenth of the whole number indicated by that circle. If the lowest circle is marked 100, a 0 must be affixed to the reading to occupy the units place. If a hand is on or near a number, read that number instead of the next lower number when the hand in the next lower circle is on or past 0. (NOTE: On cubic feet dials on some small meters there is a circle marked one or one foot. This circle is for testing only and is not part of the reading. A complete revolution of this hand equals one cubic foot.)

Figure 10-7 shows a vertical register for a flow meter. The setting knob for the hands projects through the dial. This meter has two hands for a more accurate recording of the rate of flow of a fluid. The gallon hand on the meter illustrated stands on 40 and the fraction hand stands on 0. If the fraction hand were on



61.14X

Figure 10-7.—Vertical register for a flow meter.

4 on the outer circle of the dial, the reading on the meter would be 200.4 gallons.

Depending upon the quantities, fluid rates, and types of fluid involved, measurement of flow can be accomplished by a number of means. Several devices, such as positive displacement meters, velocity meters, and venturi differential pressure meters, have been developed for measuring fluid flow. All fluid meters are made to measure fluids of definite specific gravities and characteristics, and must be used for the purpose for which they were made. Each meter is tested and calibrated before it is shipped from the factory. The discussion which follows is concerned primarily with the fluid flow meters that find relatively wide application aboard naval ships.

DISPLACEMENT METERS

Positive displacement meters are used to measure the quantity of flow of such liquids as

water, fuel oil and other petroleum products and chemical solutions. The classification of meters specified for naval use is as follows:

1. Fuel-Oil
 - a. Medium pressure meters for boiler service.
 - b. Low pressure meters for oil engine service.
 - c. Low pressure meters for fueling service.
 - d. High pressure meters for boiler service.
2. water
 - a. Cold water meters, for water up to 100° F.
 - b. Hot water meters, for water up to 180° F.

Additional information concerning percent of actual quantity at flow and viscosity can be obtained from manufacturers' technical manuals for specific equipment.

In a positive displacement meter, each cycle or complete revolution of a measuring element displaces a definite, fixed volume of liquid. Measuring elements used in positive displacement meters include disks, pistons, lobes, vanes and impellers. The motion of these devices may be classified as reciprocating, rotating oscillating, or nutating, depending upon the type of measuring element used and the general design of the meter read-out or register.

Description

A positive displacement meter of the nutating-piston type (commonly used by the Navy) is shown in figure 10-8. The flow of oil through the meter causes the piston (also called a disk) to move with a nutating motion. Understanding the nature of this motion is the key to understanding the operation of the meter. A nutating motion (fig. 10-9) might be described as a "rocking around" motion; it is similar to the motion of a spun coin just before the coin settles flat on its side. The piston in the meter cannot settle flat on its side like a spun coin since the piston is nutating (or rocking around) on a lower spherical bearing surface.

The piston cannot rotate because it is held in place by a fixed vane or guide that runs vertically through a slot in the piston. However, the nutating motion of the piston imparts a rotary motion to the pin that projects from the upper spherical surface. The rotary movement of the pin rotate

the gears, and the movement of the gears actuates a counting device or register at the top of the meter.

Although the action of the nutating piston is smooth and continuous, there is nevertheless a definite cycle involved in the measurement of liquid flow through this meter. The nutating action of the piston seals the measuring chamber off into separate compartments, and these compartments are alternatively filled and emptied. (NOTE: This action is described more fully later in the section.) The meter is properly classed as a positive-displacement meter, since each compartment holds a definite volume of

the liquid. (NOTE: The nutating disk is held in the nutating position by the control roller which prevents it from assuming a horizontal position.)

Totalizing meters have a read-out in gallons or pounds of liquid; however, they may also indicate rate of flow in gallons per minute (gpm) or in other flow units.

The heart of the meter is the measuring chamber and the disk piston. Parts A and B of figure 10-10 show how the disk is located in the measuring chamber. Part C of figure 10-10 is a sectional view illustrating one-half of the measuring chamber. It is bound at the top and bottom by conical surfaces (1) and (2), which are

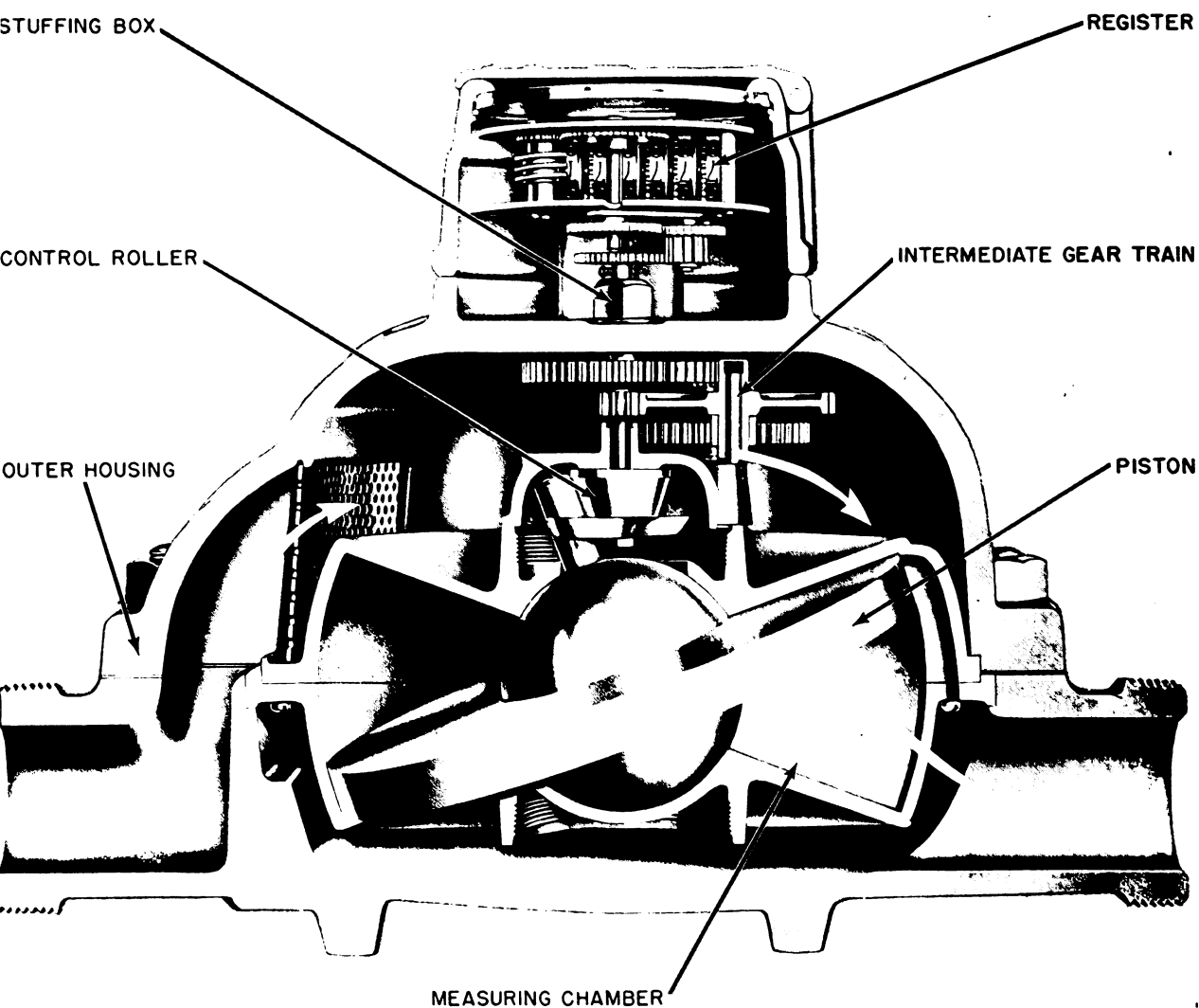
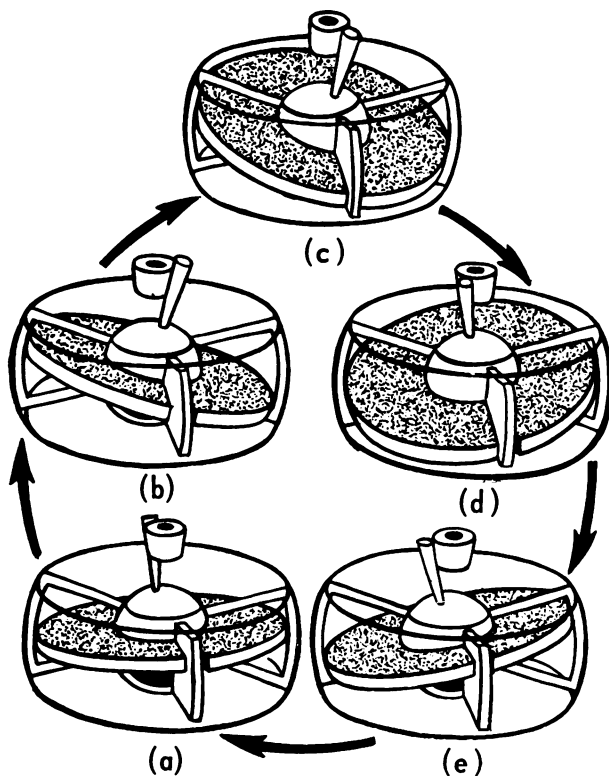


Figure 10-8.—Nutating-piston meter for measuring liquid flow.

38.64X



38.66X

Figure 10-9.—Diagram showing nutating motion of piston and rotary motion of pin in nutating-piston meter.

joined at their outer edges by spherical surface (3). A sectional view of the entire meter is illustrated in figure 10-8.

Referring to parts A and B of figure 10-10, the upper and lower surfaces of the chamber converge towards the center to form a spherical cavity for the ball (4), through which passes the nutating disk pin (5), which is connected with the intermediate gear train (fig. 10-8). Disk (6), shown in figure 10-10, is attached to the ball. Both the ball and disk are machined to fit closely in the chamber. There is a slot (8) in the disk at one point, through which passes the thin partition (7) which cuts the chamber in two. There are openings in the outer wall of the chamber on each side of the partition. Opening (9) is the fluid inlet, while opening (10) is the outlet.

When the ball carrying the disk and the nutating disk pin is tilted as far as it can go, the bottom of the disk makes a close contact with the bottom conical surface of the chamber,

while the top of the disk similarly contacts the upper conical surface of the opposite end of the disk. Since the disk is flat while the contacting surfaces are conical, contact takes place along a straight line on each surface. The lines of contact produce seals, which when taken in connection with the partition (7), divide both the upper and lower compartments into two parts. The net effect is that the disk and partition produce four separate compartments in the measuring chamber, two above the disk and two below. The top and bottom compartments are separated from each other by the disk, while the pairs of compartments respectively above and below the disk are separated by the seal formed at the line of contact between the disk and the conical top and bottom surfaces, and also by the partition.

The nutating disk pin (5), referred to as a spindle by some manufacturers, rises from ball (4) and passes through wheel (11) at a point near its outside edge. Vertical shaft (12) is attached to the control roller, or wheel (11) and rotates with it. This shaft is connected at its upper end to the intermediate gear train, and is mounted directly over ball (4). When the control roller or wheel (11) turns on its axis, the position of the shaft keeps the nutating disk pin inclined at just the angle to produce a continuous seal between disk (6) and the upper and lower surfaces of the measuring chamber.

For the purpose of simplicity, consider the meter as a pump driven by some outside force. The action of the meter can be understood by imagining wheel (11) to be revolved by means of shaft (12). The nutating disk pin would revolve with it, and would trace a conical path in space, as shown in figure 10-11. This movement of the nutating disk pin would control the positioning of the disk. When the nutating disk pin is in position (A), for example, the disk would also be in position (A), while the positions (B) and (C) for the disk pin and disk would also correspond.

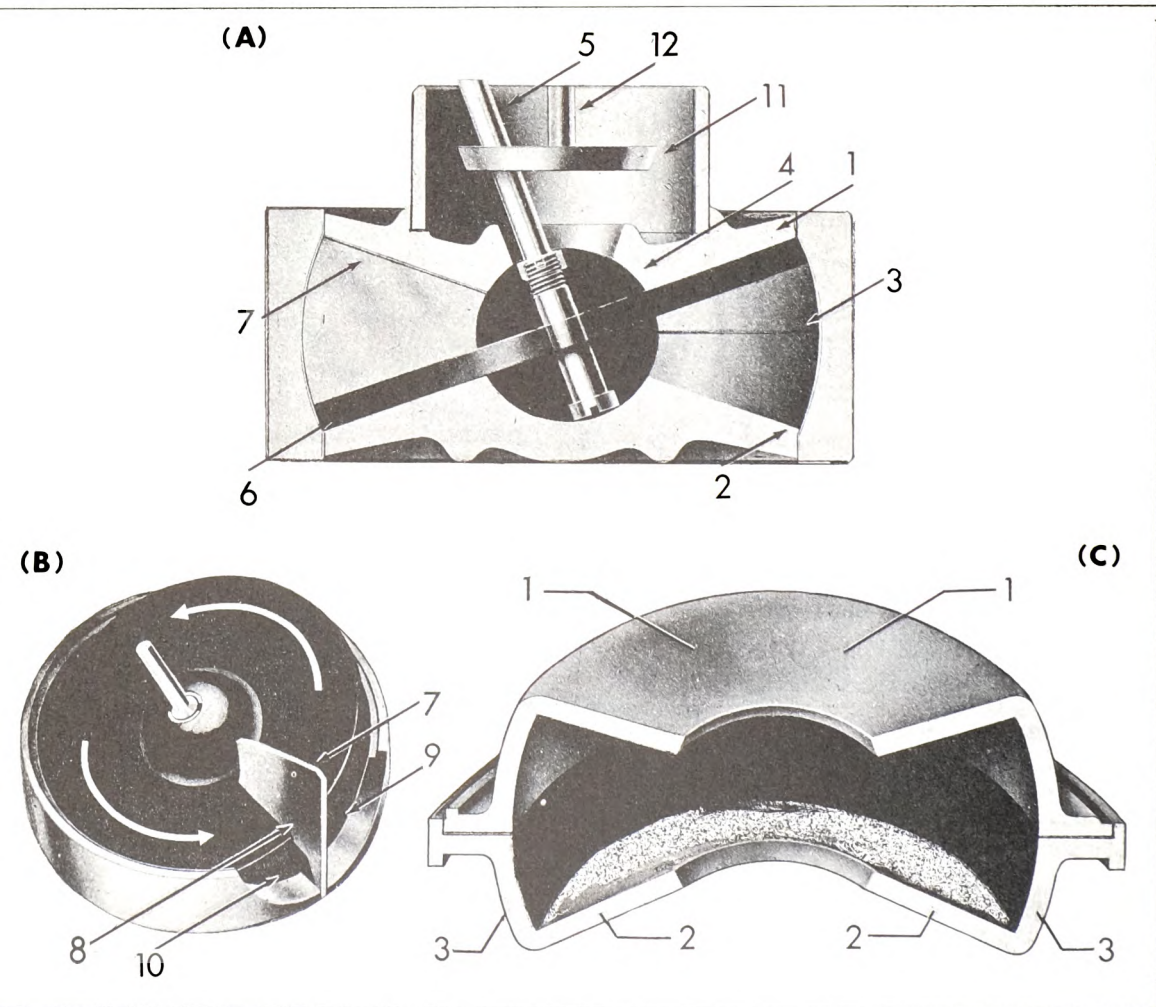
The disk cannot rotate, because partition (7), shown in figure 10-10, stands in slot (8). The disk, therefore, wobbles up and down (nutates) while the seal lines, formed by the disk and the top and bottom walls of the measuring chambers, are made to revolve around the chamber.

For further simplicity, consider only the lower portion of the chamber. The seal will always belong to the line which has the greatest inclination. As this seal line moves in the direction shown by the arrows in figure 10-8,

will sweep the fluid before it can cause it to be discharged through the opening (10) of figure 10. At the same time it will be opening up increasing volume in the compartment behind moving line of the seal. Since this space is to the inlet (9), it is filled with fresh fluid. As the line of seal passes the partition (7), the liquid formerly in front of the seal will be forced out of the discharge. The line then starts to push the fluid, which

was formerly behind it, forward. The line of flow of the fluid is as shown in figure 10-8.

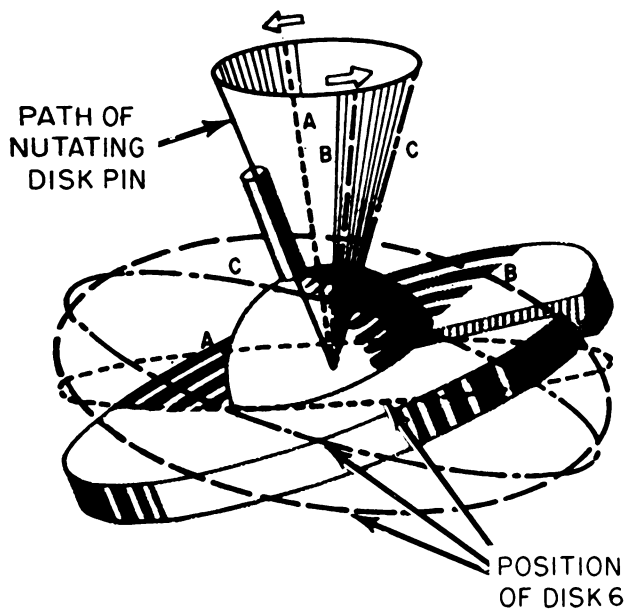
Obviously, if the control roller, or wheel (11), shown in figure 10-10, were continuously rotated, the disk (6), would move a volume of fluid equal to the volume of the lower half of the chamber from the inlet to the outlet, for every rotation. During this same revolution, the top section is doing the same, except that its seal is always directly opposite the lower seal



- | | |
|--|-------------------------------|
| 1. Measuring chamber (top surface). | 7. Chamber partition. |
| 2. Measuring chamber (bottom surface). | 8. Slot. |
| 3. Measuring chamber (outer edge). | 9. Inlet opening. |
| 4. Ball. | 10. Outlet opening. |
| 5. Nutating disk pin. | 11. Control roller, or wheel. |
| 6. Disk. | 12. Shaft. |

Figure 10-10.—Nutating piston disk flow meter (sectional views).

38.66(61C)



61.190

Figure 10-11.—Operation of disk and disk pin of nutating-piston meter.

in the measuring chamber. Therefore, for every revolution, the piston will displace the volume of the entire chamber just once.

In the previous discussion, the meter is described as though it were a pump operated by the rotation of wheel (11). Actually the operation of the meter is just the reverse. It is operated by the slightly greater fluid pressure at the inlet as compared with the outlet. This pressure differential causes the seal line to advance around the measuring chamber, and in doing so it rotates wheel (11). This in turn revolves the indicating register of the meter by means of shaft (12) and suitable reduction gearing.

Standard meters of this type are suitable for temperatures to 200° F, and for pressures to 150 psi, although models are available for higher temperatures and pressure. The meters are accurate to about one percent or less. The accuracy of the meter is not affected by pressure variations.

Installation, Care, and Maintenance

It is important to use the correct size meter for the flow range to be measured, regardless

of the system pipe size. When installing a meter, see that it is the proper type meter for the service in which it is to be used, e.g., cold water meters must not be used where temperatures will rise above 100° F. Observe the directional arrow markings on the meter—the flow through the meter should always be in the indicated direction.

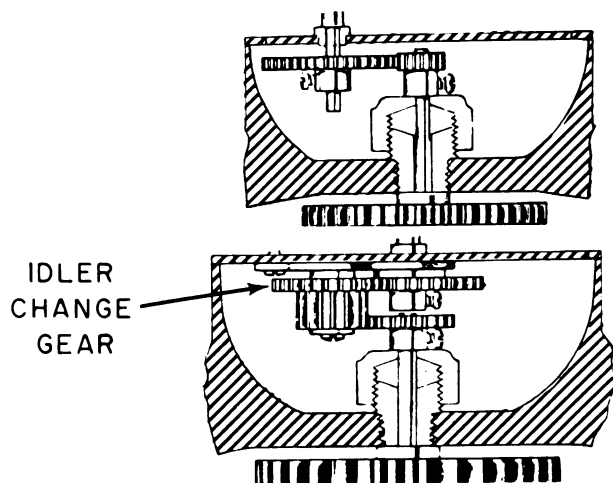
It is recommended that bypass piping be installed with the meter to permit continuous flow through the system whenever the meter must be removed for service. This not only applies to positive displacement meters but to all types of meters described in this chapter.

Some of the difficulties which you may encounter in working with meters are:

1. Inaccurate registering.
2. Leakage of metered liquid.
3. Uneven motion of dial hand.

These difficulties are discussed briefly in the following sections. For additional details about these difficulties, and other factors concerning repair and maintenance of meters, consult the manufacturers' technical manuals.

INACCURATE REGISTERING.—If a fluid meter runs at an inaccurate rate by a fairly constant percentage, the difficulty may be caused by faulty original calibration at the factory, slight wear in the mechanism, or a change in the viscosity of the liquid being measured.



61.15

Figure 10-12.—Change gears in a fluid meter.

Each meter has a set of change gears located immediately beneath the register. They are made with different numbers of teeth so that different combinations of gears can be used to give different speed ratios, as required. These change gears (two different types) are shown in figure 10-12.

In the lower part of figure 10-12 you can see an idler change gear, which is used between the other gears to give greater flexibility of gear ratios. The idler gear may have 15 to 48 teeth; its pinion always has 15 teeth. Because change gears may be causing inaccurate registering of the meter, run accuracy tests as directed by the manufacturer's technical manual; and, when necessary, follow the manufacturer's instructions for determining the type and size of new change gears needed as replacements.

In making accuracy tests, take into consideration the following factors which affect the accuracy of measurement of a meter:

1. **WEAR.** Wear causes a meter to register less than the true quantity of liquid delivered, usually at low rates of flow. **CORRECTION:** Replace the change gears, if the wear is more than 3 percent, replace the chamber and the disk piston.

2. **AIR OR VAPOR.** The passage of air, steam, or any other gas, through a meter is registered along with the liquid. **REMEDY:** Eliminate gas at its source; if necessary, install an air release valve in the line ahead of the meter.

3. **FOREIGN SUBSTANCES.** Solid matter in the measuring chamber impedes the movement of the piston, and causes underregistration. **REMEDY:** Trap the foreign matter with a filter or strainer.

4. **CHANGE OF VISCOSITY.** If the viscosity of a liquid being measured decreases, registration in the meter decreases, and vice versa when the viscosity of the liquid increases. **REMEDY:** Replace the meter if you have one with correct calibration.

5. **CHANGE OF TEMPERATURE.** If the temperature of a liquid changes substantially, registration in the meter may change slightly due to changes in the viscosity and properties of the liquid. **REMEDY:** Disregard temperature changes of plus or minus 25° F, and follow the manufacturer's instructions for greater changes.

6. **CHANGE IN THE RATE OF FLOW.** At full flow, a meter usually registers slightly less than the true quantity delivered; the proportionate registration increases with a decrease in the rate of flow until at about 5 to 10 percent of maximum cold water or oil capacity, when the meter registers slightly more than the true quantity.

If a meter underregisters by a substantial or erratic amount, it may be partially clogged up with some substance, or the mechanism may be badly worn. Disassemble the meter and remove the foreign substance, or replace worn parts. Sometimes, installation of a new meter may be required.

LEAKAGE OF METERED LIQUID.—A leakage of liquid where the register is connected with the meter body indicates that (1) the stuffing box packing has become loose, (2) the temperature may be too high for the packing used, or (3) the shaft may be scored. If repacking is necessary, follow the manufacturer's instructions for repacking the stuffing box, and use approved packing only. If the shaft is scored, replace it and install a new top intermediate gear.

Leakage around the main flange of a meter usually indicates that (1) the operating pressure is above that for which the gasket was intended, (2) the temperature is too high for the gasket, or (3) the meter was not correctly reassembled after repair. In bronze case meters it is also possible that excessively high pressure has warped the outer casing, causing a leak midway between the bolts. Leakage at couplings indicates the absence of washers, or defective washers. If the pipe is not correctly aligned, washers will not hold tight. Leather washers are good for using with cold liquids but they burn out under high temperatures. Replace leather washers with asbestos washers in meters used to measure liquids at high temperature.

UNEVEN MOVEMENT OF DIAL HAND.—If the dial hand of a fluid meter alternately stops and jumps ahead, there is probably trouble in the gears, usually meshing of the change gears. The gears may be worn to such an extent that the tops of the teeth strike on each other, or the gears may mesh too tightly as a result of faulty adjustment. To correct this difficulty, adjust the change gears so that they mesh smoothly with just enough clearance to prevent binding.

Flow Meter Test Stand

As an Instrumentman, you will be required to operate and perform routine maintenance on a fluid flow meter calibration stand, as well as other test equipment, in accordance with MIRCS procedures. Figure 10-13 shows a schematic diagram of a flow meter test stand. The comparison method, using the flow test stand, is described in the paragraphs which follow.

The flow is directed through a standard meter and a test meter connected in series. At the end of a timed run, an error in the standard meter is found and compensated for. This value is compressed with the reading on the test meter and the error in the test meter is determined. (NOTE: When operating the flow test stand, NEVER leave a valve HARD OPEN; always back off 1/2 turn, unless specified otherwise in the operating procedure. If a valve is left HARD OPEN and then cold water is run through it, the valve will jam.)

PRIMING THE SYSTEM.—When the piping system has been drained of water, the sudden shock of turning on the unit with air in the lines could damage the meters. Provisions must be made to fill the system slowly so that the meters won't be struck with a solid wall of fluid when the system is energized.

To prime the system, refer to figure 10-13 and proceed as follows:

1. Ensure that all valves are OPEN.
2. Position the 3-way valve (V-5 shown in fig. 10-13) to direct the flow through the meters.
3. Close valves V-3 and V-4.
4. Energize both power boxes. (CAUTION: HIGH VOLTAGE, HIGH AMPERAGE)
5. Turn master control lever to ON.
6. Press START button.
7. When the pump has reached the maximum rpm, slowly begin opening V-4.
8. Continue opening V-4 until it is completely OPEN, then back off 1/4 turn.
9. Open V-3, as you did V-4. (NOTE: The system is now primed and you are ready to begin the operation of the test stand.)

OPERATION.—To operate the system, proceed as follows:

1. Slowly begin closing down V-2 and V-7 simultaneously. Watch the rotameter and the pressure gages, and adjust the rate of flow and line pressure to the desired values.

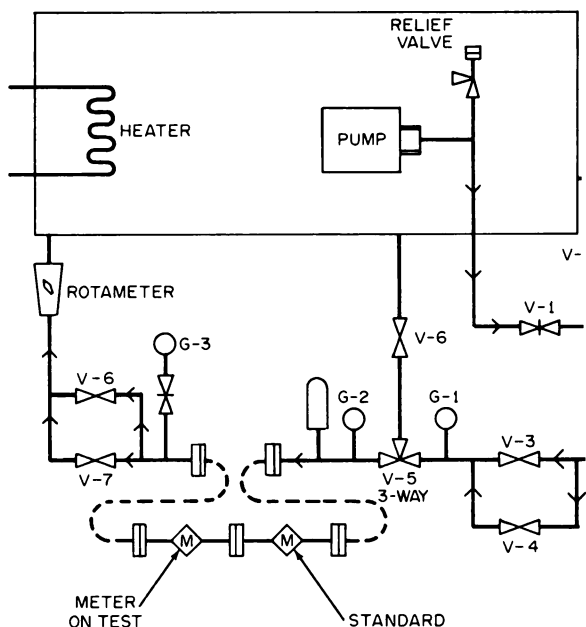


Figure 10-13.—Flow meter test stand—schematic.

2. With a firm snappy action, turn V-2 ninety degrees to direct the flow through V-2 and back into the tank.
3. Slowly close down on V-6 until the pressure on G-1 matches what you just set up through the meters on G-2.
4. You are now ready to calibrate.
5. Reset both meters to zero.
6. At a timekeeper's signal, shift flow through the meters. (NOTE: to ensure accuracy, at least 100 gallons of liquid should be run through the meters. Set duration of run accordingly.)
7. Open V-6.
8. Record information from meters and set up for next run.

To secure equipment, press STOP button, shift master control lever to OFF/LOCK position, and OPEN all valves.

Figure 10-14 shows a flow meter calibration checklist. The nomenclature required for

completion of a calibration checklist is itemized and defined in the listing which follows:

1. Nominal Rate G.P.M. Rate in gallons per minute which you have set up on the rotameter for the flow test stand to operate at.
2. Pressure (P.S.I.) Pressure you have set up on G-2 for the test stand to operate at during the calibration run.
3. Temperature Temperature of the fluid used in the calibration run
4. True Volume Standard meter reading multiplied by it's meter factor
5. Indicated Volume Reading taken from the test meter
6. Duration Minutes Actual time that the flow stand was in operation with fluid flowing through the standard and test meter.
7. True Rate G.P.M. Divide the true volume by the duration minutes.
8. Indicated Rate G.P.M. Divide the indicated volume by the duration minutes
9. Tolerance Error allowed in the meter (Fed or Mil or Mfg Specs.)
10. Out of Tolerance Check only if meter is of tolerance
11. Meter Factor Divide the true volume by the indicated volume to give you the meter factor of the test meter.

Calibration

The most accurate way to calibrate a positive displacement meter is to pass a measured amount of liquid through the meter at a given rate. This is generally accomplished with a system whereby a liquid of known specific weight is collected and weighed after being run through the meter for a measured time. Its volume and rate are then calculated and compared with the meter register readings to obtain a percentage error, if any, at a given rate. Several criteria for this test are listed, as follows:

1. The meter should be tested with the liquid it is to meter (or one of similar characteristics), and at nearly the same temperature as that at which it will be used. (Temperature affects both

the dimensions of the meter and the viscosity as well as the density of the liquid.)

2. The meter should be tested over the range of rates of flow at which it will be used.

3. The liquid should be free of entrained air or vapor because these will be registered as liquid.

4. The volume of the reference container should be at least sufficient to hold the quantity which will pass through the meter in one minute when the meter operates at its rated capacity.

The indication of the register can be adjusted to coincide with the actual quantity over a considerable portion of the operating range by changing the gear ratios of the meter. This is generally not performed unless the meter is grossly out of calibration. Instead, when the meter is calibrated, curves are plotted of meter correction factor vs indicated flow rate from which meter register readings may be corrected. Figure 10-15 shows a typical positive displacement meter correction curve.

A less accurate means of checking and calibrating a positive displacement meter is by running it in series with a master meter. The test meter readings are compared with those of the master meter corrected by curves provided with the master. Then a correction factor curve may be plotted for the test meter.

VELOCITY METERS

The velocity of a linearly flowing fluid is converted into a rotary spindle motion by means of velocity meters. These meters are used to measure liquids such as water and low viscosity fuels. Use with fuels of high viscosity is limited to special applications such as high flow rate fuel transfer.

Accuracies of $\pm$ one-half percent may be achieved by velocity meters in clean liquid service at steady specific gravities. (The accuracy of velocity meter depends to varying degrees, upon the temperature, pressure, and characteristics of the fluid.)

The velocity meters described in the section are the propeller and turbine type meters. Fluid flowing through the meter drives a propeller or turbine wheel at a speed varying with the rate of flow.

Description

Figure 10-16 illustrates a propeller type flow meter, where a propeller drives a gear train or

FLOWMETER CALIBRATION CHECKLIST

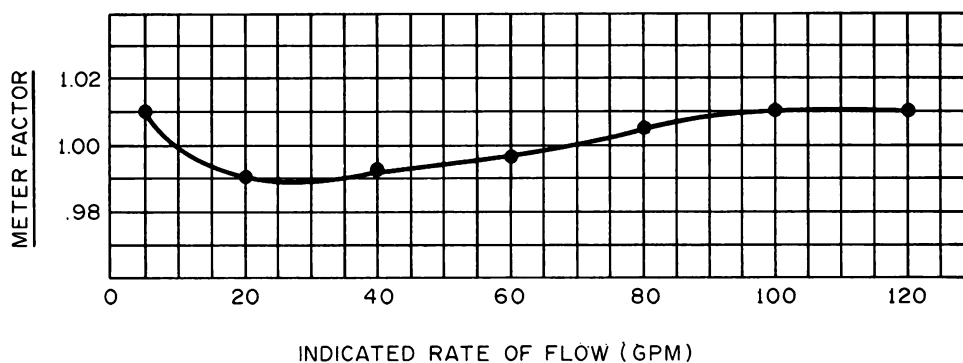
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Figure 10-14.—Flow meter calibration checklist.

magnetic drive connected to a direct or remote counter, or indicator, which register the total quantity of fluid passing through the meter. If the specific weight of the fluid is known and constant, the counter may be made to indicate weight. In this respect velocity meters resemble positive displacement meters which give total quantities directly, and not rates of flow. However, velocity meters are quite distinct from positive displacement meters in that they do not pass the fluid through in separate portions. The propeller or turbine of a velocity meter need not take up the entire line cross section, and fluid can pass with little obstruction. (NOTE: A

particular type of gear driven propeller meter which deserves brief mention is the anemometer. This instrument is used to measure air and gas flow, usually indicated in feet per minute. Another propeller meter is the submarine triometer in which the indicator is mounted remote from the meter head, connected by a flexible cable, and registers in thousands of pounds.

The turbine meter, shown in figure 10-1, is similar to the propeller flow meter. The meter uses a turbine wheel made of a magnetic material. A permanent magnet is mounted on the casing pipe surrounded by a pickup coil. As the blades cut the lines of magnetic force,



(THE ACTUAL RATE OF FLOW IS
OBTAINED BY MULTIPLYING RATE OF FLOW BY
THE METER CORRECTION FACTOR)

61.193

Figure 10-15.—Typical positive displacement meter correction curve.

current is induced in the coil, producing an electrical pulse. Since the pulse frequency varies with the velocity of the fluid flow, cycles per unit time may be converted to quantity or flow rate from the value of a K-factor (cycles/gallon) given for the meter. For this purpose, a pulse receiver is used to indicate either a totalized quantity reading or a flow rate. (NOTE: All types of meters have a K-factor; however, they are all defined differently. For example, the K-factor for venturi, nozzle, and orifice meters is defined as the product of the discharge coefficient, which corrects theoretical flow to actual flow, and the velocity of approach factor. The use of the K-factor in a flow equation results in "actual" flow, not theoretical flow. Additional information on K-factor can be obtained from the manufacturer's technical manual for the specific meter.)

Installation and Operation

Before installation, place the meter in a horizontal position and blow into the inlet port. The rotor should turn freely, with no evidence of roughness or binding. A sufficient length of straight pipe should be provided before and after the meter to minimize irregularities in the flow pattern which have an adverse effect on the meter accuracy. Lengths of ten pipe diameters upstream and five diameters downstream are

commonly employed. If this cannot be accomplished, straightening vanes (fig. 10-17) should be installed in the pipe upstream of the meter. (The straightening vanes shown in figure 10-17 are built into this flow meter. Some meters are equipped with vanes, which are not built into the unit, and internal tube type flow straighteners. Information on these devices can be obtained from manufacturers' technical manuals for specific units.)

The meter should be mounted in the line just as though it were a short length of pipe. In newly installed or modified piping systems, the line should be flushed before the meter is installed; this minimizes possible damage from foreign materials. On remote reading indicators the cable from the meter should be shielded and grounded at the readout. Meters may be operated in any position, but horizontal is the favorite installation position.

Operation of velocity type flow meters is entirely automatic except where a reset or incremental totalizer is included on the indicator. This must be hand set on zero at the start of a run. CAUTION: Do not reset mechanical counters while the meter is operating.

After flow has started through the meter, check that the indicator is functioning. The liquid being metered should be free of foreign materials which could foul the meter. It should also be free of entrained air which will result in an inaccurate reading.

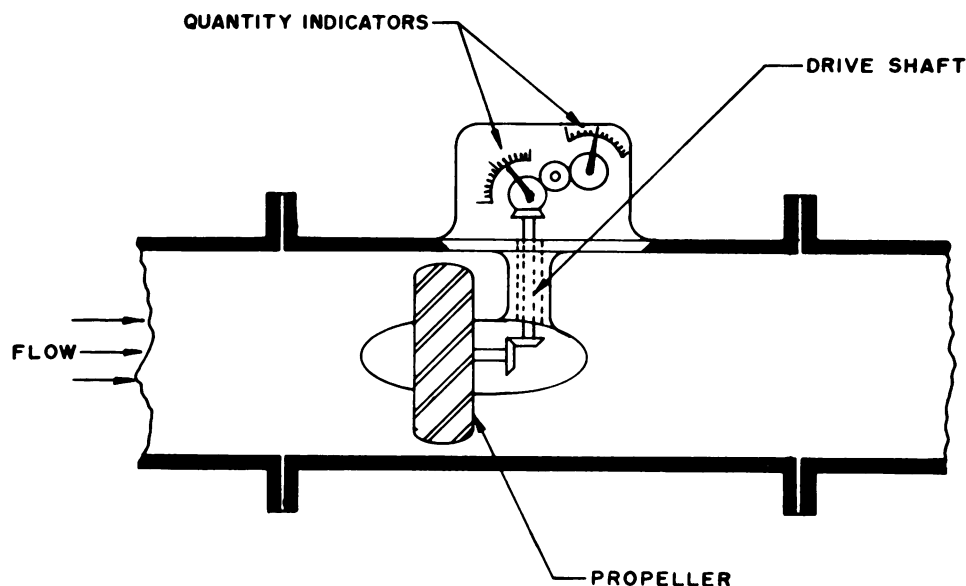


Figure 10-16.—Propeller meter.

61.194

Maintenance and Calibration

Inspect moving parts of the meter for smooth operation, and lubricate at definite time intervals in accordance with manufacturer's recommendation for a specific meter. Where spare parts are available, repairs and replacements should be made only by experienced instrumentmen. In certain cases, it will probably be best to replace the entire meter and return the faulty one to the manufacturer.

Whenever a rotor of a meter is replaced, the meter must be recalibrated. However, when only bearings are replaced, recalibration of the meter is not necessary.

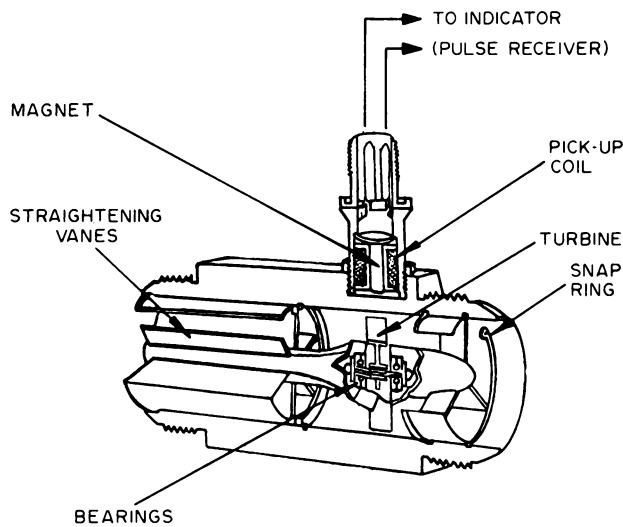
When a meter is disassembled, clean all metal parts with solvent. Do not use solvent on the propeller if it is made of plastic; carefully clean and scrape it so that the blades offer smooth surfaces to the flow. The propeller and turbine type flow meters are calibrated by the manufacturer(s) for a specific fluid.

For calibration of meters having an electrical readout, an electronic counter may be used as an additional check on the indicator accuracy. This unit counts cycles per unit time which can be

converted to quantity of flow rate by use of the meter K factor, mentioned previously.

VENTURI DIFFERENTIAL PRESSURE METERS

Venturi differential pressure meters, or head meters, sometimes referred to as head obstruction meters, measure fluid flow by measuring the pressure differential across a specially designed restriction in the flow line. The restriction may be an orifice plate, a flow nozzle, a venturi tube, an elbow, a pitot tube, or some similar device. (The venturi is the device most commonly used in shipboard systems, such as fuel oil transfer.) As the fluid flows toward the restriction, the velocity decreases and the pressure (or "head") increases; as the fluid flows through the restriction, the velocity increases and the pressure decreases. Figure 10-18 illustrates the pressure changes that occur as a fluid flows through a line that contains an orifice plate or similar restriction. Note that there is a slight increase in pressure just ahead of the restriction and then a sudden drop in pressure at the restriction. The point



61.195
Figure 10-17.—Turbine meter.

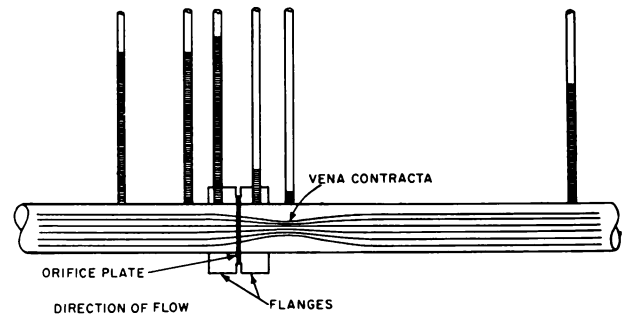
of minimum pressure and maximum velocity is slightly downstream from the restriction; this point is called the vena contracta. Beyond the vena contracta, the velocity decreases and the pressure increases until eventually normal flow is reestablished.

The flow nozzle, orifice plate, or other restriction in the line is called the primary element of the head meter. A high pressure tap upstream from the restriction and a low pressure tap downstream from it are connected to a differential bellows, a diaphragm, or some other device for measuring differential pressure.

The pressure drop occurring in a fluid flowing through a restriction varies as the square of the fluid velocity; or, to put it another way, the square root of the pressure differential is proportional to the rate of fluid flow. Because of the square-foot relationship between the pressure differential and the rate of fluid flow, a square-root extracting device is usually included so that the scale can be graduated in even steps or increments. Without a device for extracting the square root of the pressure differential, the scale would have to be unevenly divided, with wider divisions at the top of the scale than at the bottom.

Description

The distinctive feature of head meters such as the venturi tube is that means are employed



147.59
Figure 10-18.—Pressure changes in fluid flowing through restriction in line.

to cause a marked change in the static pressure of the fluid while it is passing through the meter.

The venturi tube, usually inserted between two flanges in a pipeline, is made up of a short constricted portion between two tapered sections. With the constriction it accelerates the fluid flowing and temporarily lowers its static pressure. Pressure connections are provided for observing the difference in pressures between the inlet and the constricted portion, or throat. This difference in pressure is measured in appropriate units for an indication of flow rate. (NOTE: A Barton gage or a manometer connected between the throat and inlet can be used to indicate the rate of flow.)

Figure 10-19 illustrates a venturi tube in which it shows that the straight inlet, entrance cone, straight constricted portion or throat, exit cone, and outlet are all joined by curved surfaces. This reduces resistance, minimizes wear and assures a smooth, full flow. Static pressure of the fluid at the inlet and the throat may be obtained through a single side wall hole, or through several holes evenly spaced around the section leading into a piezometer ring from which a single connection is made. The throat and the inlet portions of the venturi tube are always machined or cast very smooth—exact determination of their diameters is essential to the precise measurement of flow by the meter.

One modification of the basic venturi tube is the reversible flow tube where flow in either direction may be measured. The tube is made symmetrical with a throat tap at the center and an inlet tap at each end. A differential pressure sensor is connected to each inlet tap and the throat tap. With both sensors on the line,

flow direction is indicated by the highest reading.

Differential pressure from the taps may be measured by any common differential pressure element. Most instruments either indicate or record the differential head, or convert it into units of flow rate such as cubic feet per minute or gallons per minute.

Installation and Operation

The meter is installed in the line as a section of pipe with flanged connections. Pressure taps are usually 1/4 inch tube or 1/4 inch IPS. The preferred installation of pressure tap lines should provide a three valve manifold assembly similar to that used for manometers so that a zero setting can be obtained on the differential pressure sensor. In liquid systems an air bleed should also be provided for venting the sensor to ensure a complete liquid fill.

A long continuous run of straight pipe (20 diameters minimum upstream and five diameters minimum downstream) must be provided to obtain accurate results from a differential pressure meter. The upstream distance may be made smaller by using a flow straightener such as a tube bundle or straightening vanes.

Excessive pipe roughness or heavy sediment must be avoided as they will cause inaccuracies of indication.

Once installed, the venturi tube operates automatically whenever flow exists. If valves are located in the pressure tap lines, see that they are open. Make certain that the indicator is energized when readings are to be taken. When an air bleed is provided on liquid system sensors, vent the system before taking a reading. When a three way valve manifold is provided, set zero on the sensor before taking a reading.

Maintenance and Calibration

In general, except for periodic checks, maintenance of the venturi tube is not required. The condition of the inner surface of the tube should be checked periodically; especially at the inlet and throat portions of the venturi tube. If these portions become worn, rough or eroded, the meter must be replaced.

The holes leading to the pressure taps should also be checked for signs of clogging. Carefully clean them out, where necessary. On some fuel oil meters two pipe taps are installed on the entrance section to which steam and drain lines may be attached. A few minutes steaming out will clean the chamber surrounding the throat and the pressure taps. The small amount of condensed steam which enters the flow line will settle in the storage tank to be drained off with the sediment.

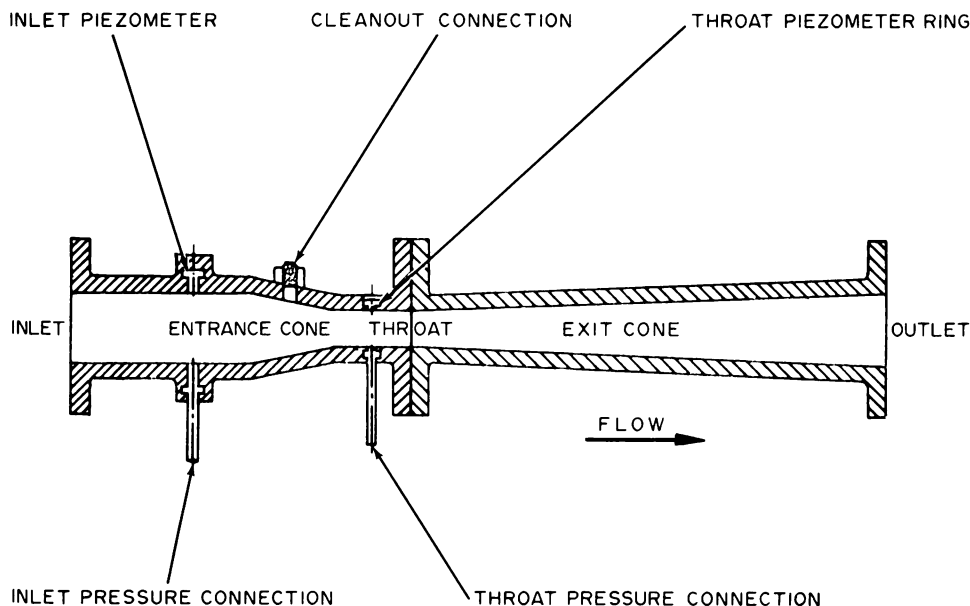


Figure 10-19.—Venturi tube.

38.191(61)C

Calibration of venturi meters should only be accomplished by the manufacturer or a suitable Naval Laboratory.

AREA METERS

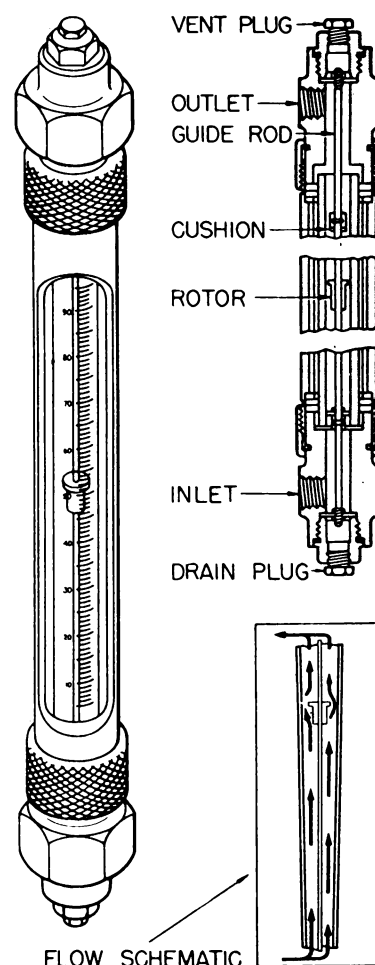
An area meter indicates the rate of fluid flow by means of an orifice that is varied in area by variations in the fluid flow. The variations in the area of the orifice are produced by some type of movable device which is positioned by the pressure of the flowing fluid. Since the fluid itself positions the movable device and thus varies the area of the orifice, there is no significant pressure drop between the upstream side and the downstream side of the variable orifice. Since there is an essentially linear relationship between the area of the orifice and the rate of flow, there is no need for a square-root extracting device in an area meter.

Most area meters are classified as (1) rotameters, or (2) piston-type meters, depending upon the type of device used to vary the area of the orifice.

Description

A variation in the cross section of the flow stream, under constant differential pressure across the meter, is used as an indication of the rate of flow in area meters. The differential is maintained constant by a free floating element which rises and falls as the flow rate changes. When the float rises, the metering area is increased. The amount of rise of the float is governed by its weight and the force of the flowing fluid. The height of the float is translated to an indication of the rate of flow.

A simple rotameter type area meter, used in some shipboard distilling plants, is shown in figure 10-20. This figure illustrates the operation of a rotameter. The most widely used form of area meter is the tapered tube and float or rotameter as shown in figure 10-21. A float is suspended in a vertical tapered tube and moves axially with the flow, which is vertically upward. The weight of the float, minus its buoyancy in the fluid, is balanced by the drag force of the fluid upon the float. The float rides at a height that will maintain this balance of forces. Glass is generally used for the tube material, but plastic and metal are also employed. Glass and clear plastic tubes have a scale etched on them whereby the position of the float may be directly determined.



75.290
Figure 10-20.—Area meter (rotameter type) for measuring fluid flow.

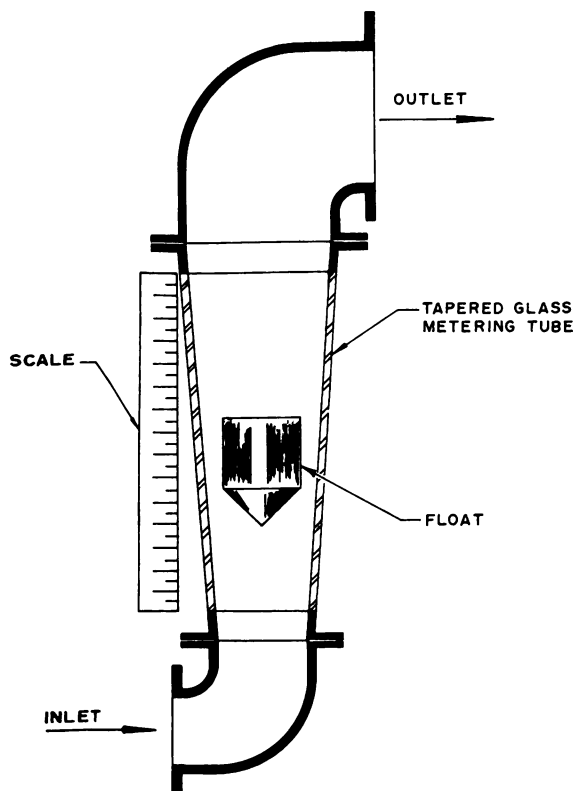
The tube is graduated either in flow rate or in percent of full flow with an additional external metal scale calibrated in flow rate mounted beside the tube. When the scale is graduated only in flow rate, the meter is intended for measuring one fluid of a given specific weight; use with fluids of other specific weights will cause errors. However, when the scale is graduated in percent of full flow, it may be used to measure fluids of various specific weights as long as calibration curves for the fluids are available to interpret the meter readings.

With metal tubes, indirect means are provided to observe the position of the float. One method uses a rod attached to the float and

passed through a casing tube. A magnetic follower over the casing indicates the fluid flow rate on a vertical scale above the meter.

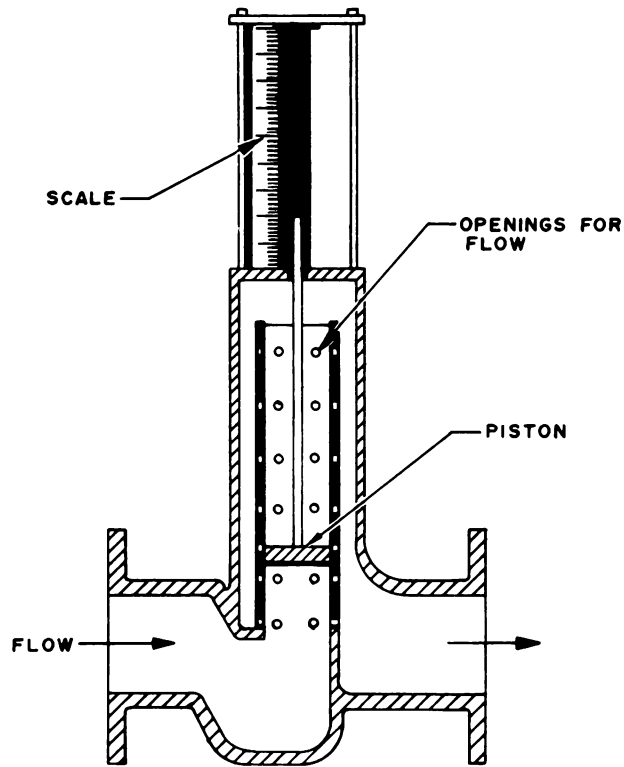
Depending on the physical properties of the fluid being metered, the shape and material of the float may vary considerably. A thin disk float will be almost independent of fluid velocity changes, while a bullet shaped float is only slightly affected by the dynamic forces due to the motion of the fluid. To overcome small changes in fluid specific weight, the float should be of material about twice as dense as the fluid being measured. Standard accuracy of rotameters is approximately $\pm$ two percent of maximum flow.

Another area flow meter is the cylinder and piston type, shown in figure 10-22. The operation of this meter is similar to that of the rotameter. The difference is that the area for fluid flow is provided by a series of reamed



61.197

Figure 10-21.—Tapered tube and float type area flow meter (Rotameter).



61.198

Figure 10-22.—Cylinder and piston type area flow meter.

holes in the walls of the cylinder. These holes are spaced in a uniform helical pattern so that the variation in area is continuous for various heights of the moving element which is a loosely fitted piston. The movement of the piston may be regulated by a weight and dash pot or a spring. With properly spaced holes in the cylinder the calibration of the instrument for flow rate is linear. A similar design replaces the multiple holes by one or more longitudinal slots in the cylinder.

A rod attached to the top of the piston moves inside a sight glass mounted above the cylinder. The position of the piston rod indicates flow rate on a suitable scale.

The cylinder and piston meter is most often employed to measure the flow of heavy fuel oils, chemical liquors, and other high viscosity fluids. It is especially useful for applications where corrosion and clogging of head meter elements is likely to occur, or where adequate information is not available on flow coefficients at low Reynolds numbers. In both rotameter and cylinder and piston meters, the

rod may be provided with an armature in a double solenoid whereby an in-bridge system is used for remote in-d recording of flow rate.

Installation and Operation

Meters must be installed vertically with the highest scale graduation at the top. For float and piston type meters must also be installed with the cylinder and piston vertical. The piston moves up with increased flow. A plumb bob or equivalent device to insure vertical alignment.

Installation is made with standard pipe connections. The cylinder and piston meter is constructed with the inlet and outlet such that it may be installed in a straight section of pipe. The rotameter, however, has an inlet at the bottom and an outlet at the top and the piping must be arranged to suit this configuration.

Generally, when a meter is to be used for gas service it should be located as closely as possible to a throttling point but preferably with the valve located at the output fitting. Inlet for gas service should be kept to a minimum.

For liquid service, however, the inlet should be as large as economically possible.

Small meters are generally supported adequately by the connecting piping, but larger meters may require additional external support.

Direct readout meters require no special support for air service.

Rotameters, plastic or metal metering tubes should be used instead of glass, where possible.

The operation of area meters is continuous and is virtually automatic. However, the following facts should be noted:

1. Do not let the flow through the meter gradually increase to too great an initial surge which may damage the float or piston assembly.

2. Check that the indicator is functioning properly when flow has begun.

3. Air or vapor must be vented from the line before the pipeline, when metering a liquid.

4. Check that the readings on rotameters are correct by noting the scale at the graduation coinciding with the leading edge of the float.

5. Keep the flow being metered free from obstructions.

Maintenance and Calibration

Except for seeing that the flow tube or cylinder is cleaned at regular intervals by swabbing it out with a suitable cleaning solution, area meters are practically maintenance free.

When disassembling a meter, follow the manufacturer's instructions for the specific meter. Be careful not to drop, or damage (in any way), the float or piston; the accuracy of the meter depends on the float remaining stable in weight and shape. When reassembling a meter, align the metering tube or cylinder to exactly its original position relative to the scale.

The area meter may be calibrated by the same methods as used for positive displacement meters, mentioned earlier in the chapter (First and most accurate, a measured amount of liquid is passed through it at a given rate. Second and less accurate, it is compared in series with a master meter.)

If the specific weight of the fluid used in making the calibration is the same as the fluid to be metered, the calibration will apply directly. However, when the fluid to be metered has a specific weight different from that of the fluid used in the calibration, this difference should be considered—especially in the metering of gases.

MAGNETIC FLOW METERS

Magnetic flow meters are used to measure the flow of conductive liquids such as water, sewage, corrosive fluids, slurries, and liquid metals. These meters are available in sizes ranging from 1/10 inch to 72 inches in diameter.

Flux meters are used to determine either the flux density, of permanent magnet instruments, at the center of the flowpipe when the flow meter is out of service or the flux leakage at a position outside the flowpipe when the flow meter is installed. A ratio of flux density at the center of the pipe to flux density measured by the leakage is provided with the flow meter. Detailed instructions on the use of the flux meter must be obtained from the technical manual supplied with the unit.

Description

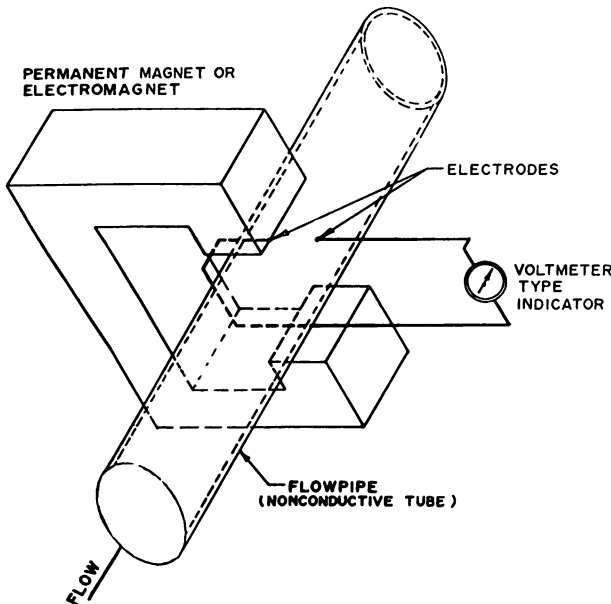
The magnetic flow meter, shown in figure 10-23, consists of a tube of nonconducting material with two electrodes mounted on opposite sides of the tube wall. The ends of the electrodes

generally penetrate the wall and are in contact with the fluid. A permanent magnet or an electromagnet, with its field at right angles to the electrodes, surrounds the tube. The flowing fluid must be an electrically conductive liquid. As the liquid flows through the nonconductive tube in the magnetic field, it acts as a moving electrical conductor and a voltage is produced which can be picked up by the electrodes. The voltage produced depends on the (1) strength of the magnetic field, (2) distance between the electrodes, and (3) the velocity of the conductive liquid flowing through the tube.

If the strength of the magnetic field and the distance between the electrodes remains constant, the voltage produced will be entirely due to the flow rate of the liquid. This voltage is then amplified and transmitted to voltmeter type indicators or recorders. The accuracy of magnetic flow meters is in the order of $\pm$ two percent of maximum flow rate.

Installation and Operation

Installation of magnetic flow meters should be performed in accordance with detailed manufacturers' instructions or NavShips technical manuals supplied with the individual unit.



61.199

Figure 10-23.—Magnetic flow meter.

In all magnetic flow meters, a flowpipe is mounted directly in the pipeline. Some units are made for welded installation of the flowpipe assembly, others have standard flanged end connections. Mounting can generally be in any position, although a vertical position is preferable.

For permanent magnet meters, pre-installation precautions must be observed, as follows:

1. Do not subject magnets to shocks or jars by dropping them or allowing any other object to strike them; any injuries to the magnets will introduce an error in the meter calibration.
2. Do not allow ferrous or other magnetic materials to come in contact with the magnets.
3. Store the magnet and pole assembly at least one foot from other magnetic materials.
4. Do not remove or replace any part of the magnetic materials which are part of the magnet and pole assembly.
5. Do not subject the magnets to excessive temperatures.
6. Use only nonmagnetic tools when working on magnetic flow meters.
7. When hoisting magnets or assembled magnetic flow meters aboard, use a nylon or manila sling instead of the customary wire rope. Keep the magnets away from steel decks and structures.

As far as the operation factors of magnetic flow meters is concerned, the pipe must be full of liquid in order that the flow measurement be accurate. No gas bubbles may be entrained in the liquid and the pipe wall must be completely wetted. Remember that permanent magnet meters give an output whenever a flow exists, and electromagnetic meters must be energized before a reading can be taken.

Maintenance and Calibration

Magnetic flow meters are designed so that they require no routine maintenance. If possible, flux density readings should be recorded at regular intervals in order to maintain a life history of magnetic performance.

Spares are provided for magnet assemblies and other replaceable parts. For specific details on the disassembly and repair of a given meter, consult the technical manual supplied with the unit.

The magnetic flow meter which can be removed from its piping system may be calibrated

by using the same methods as mentioned, earlier in the chapter, for positive displacement meters.

In permanent magnet instruments the value of the flux density (B) in the area between pole faces is a measure of the performance of the meter. If there has been a change, the sensitivity will have been altered and must be recalculated. Therefore, it is desirable to check the flux density of the flow meter when it is initially installed and at regular intervals thereafter. To calculate the sensitivity, the following equation is used.

$$\frac{Q}{E} = \frac{Yf}{B}$$

where:

$\frac{Q}{E}$ = sensitivity in flow rate/millivolt

Y = calculation factor which includes fluid and pipe temperature correction factors

f = magnet temperature correction factor

B = magnetic flux density

Values for Y and f are given with the meter, also initial values of $\frac{Q}{E}$ and B.

CHAPTER 11

TORQUE MEASURING DEVICES

Torque is based on the fundamental law of the lever; force times distance equals a moment, or torque, about a point. Torque is often called a torsional or twisting moment. It is a moment which tends to twist a body about an axis of rotation. If a wrench is used to tighten a bolt, for example, a force times a distance (a torque) is applied to overcome the resistance of the bolt to turning.

A torque wrench, or torque handle, is a gage tool which allows an applied torque to be measured and controlled. The distance of the applied force from the pivot point is held constant and the torque is shown on a scale. Usually a signaling device is included to indicate preset torques.

Torque wrenches are used to apply predetermined tension to screws, studs, and bolts. They are used whenever controlled fastening stresses are required in applications such as machinery erection, engine assembly, and pressure vessel assembly.

Torque wrenches operate basically on one of the following principles or a variation of it:

1. Deflection of a beam.
2. Deflection of a torsion bar.
3. Compression of a helical spring or springs.

Units of torque most often used, with common conversions, are as follows:

- 16 ounce-inches = 1 pound-inch
12 pound-inches = 1 pound-foot

In addition to calibrating torque wrenches, you should know what types of torque wrenches and accessories are used, how these wrenches are used, and important factors concerning torque measurement. The information which follows is supplementary to that given in chapter 4 of this rate training manual.

TORQUE MEASUREMENT

Torque may be considered to be a force acting on some point through a distance. Referring to figure 11-1, we can express torque mathematically as follows:

$$L = F \times s$$

where: F = the force in units of lbs, etc.
 s = the perpendicular distance
(frequently referred to as the moment arm) from the point (0) to the point of applying the force in units of ft, etc.
and: L = the torque in units of lb-ft, etc.

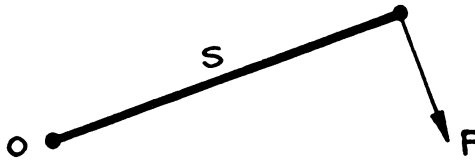
At this point you should recall, as it is stressed in chapter 4 of this rate training manual, that the units of work and torque both involve a force acting through a distance. Generally, to distinguish between work and torque, the unit of distance is given first when referencing work, and the unit of force given first when referencing torque. Thus:

Units of work = ft-lb
and: Units of torque = lb-ft
The two terms are seldom confused when taken in context; however, the difference has been presented to satisfy academic practice.

If the force in figure 11-1 creates or tends to create clockwise rotation, it is said to be a right-hand torque; and conversely, if the force creates counterclockwise rotation, it is said to be a left-hand torque.

If the distance (s) in figure 11-1 is 14 inches, and the force (F) is 12 pounds in the direction shown, what is the torque about point 0?

Substituting the information into equation ($L = F \times s$) we get:



61.200

Figure 11-1.—Torque concept.

$$L = 12 \text{ lb} \times 14 \text{ in}$$

$$L = 168 \text{ lb-in}$$

or: $L = 14 \text{ lb-ft}$

Since the torque tends to produce clockwise rotation, the torque is right handed. In the interest of brevity, the sense of the torque will not be considered in the remaining discussion.

One misleading point of the equation $L = F \times s$ is that the true torque about a point is equal to the product of the force and moment arm only if the moment arm is perpendicular to the line of action of the force.

Additional information dealing with the concept of torque and cosine error can be obtained from either manufacturer's technical manuals for specific equipments or the training manual on torque calibration, utilizing Phase D Qualification Equipment, prepared for the Metrology Engineering Center, Pomona, California. In reality, the cosine error is not applicable, and causes no problem, to the man using a torque handle or wrench to torque a bolt or other fastener. The individual need not concern himself with how the force is applied as torque wrenches sense and indicate only true torque and are not concerned with the angle at which the force is applied.

TORQUE WRENCHES

Since their development in 1930, torque wrenches have been designed and built utilizing many concepts of torque. Although hundreds of different types of torque wrenches have been manufactured, only two basic types have survived. These two types are called the flexible beam wrench and the rigid frame torque wrench. These two basic wrenches have evolved to their present state of universal acceptance because they both operate on basically sound torque principles.

FLEXIBLE BEAM TORQUE WRENCH

The flexible beam torque wrench is an instrument whose measuring element is the frame of the wrench itself. Flexible beam wrenches are simple, rugged, and reasonably accurate devices. Their design also allows them to be used for either left-hand or right-hand torque.

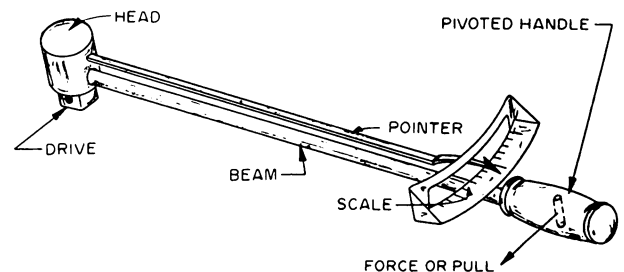
The only adjustment that can be made in the field to this type of wrench is mechanical zeroing. If a flexible beam wrench does not meet tolerance specifications, it must be returned to the manufacturer or discarded.

The most basic type of flexible beam wrench is called a round beam. The sections which follow deal with the round beam wrenches, flat beam wrenches, and tapered beam wrenches.

Round Beam Wrench

The round beam wrench which presents a rather simple, straightforward design is illustrated in figure 11-2. The head or driving element of the wrench is attached to the handle by means of a long, round beam. The length, cross sectional area, and material of the beam determine the range of the torque wrench. A scale is rigidly attached to the beam assembly just in front of the handle, and a pointer is attached to the head. The free end of the pointer rides over the scale and provides an indication (readout) of the torque applied in terms of the deflection of the beam.

The round beam or the measuring element may be considered a spring which has been designed to always be operated within its elastic limits. This means that when a force is removed the beam will restore itself to its original configuration. As force is applied to the handle, the beam deflects an amount which



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Figure 11-2.—Round beam torque wrench.

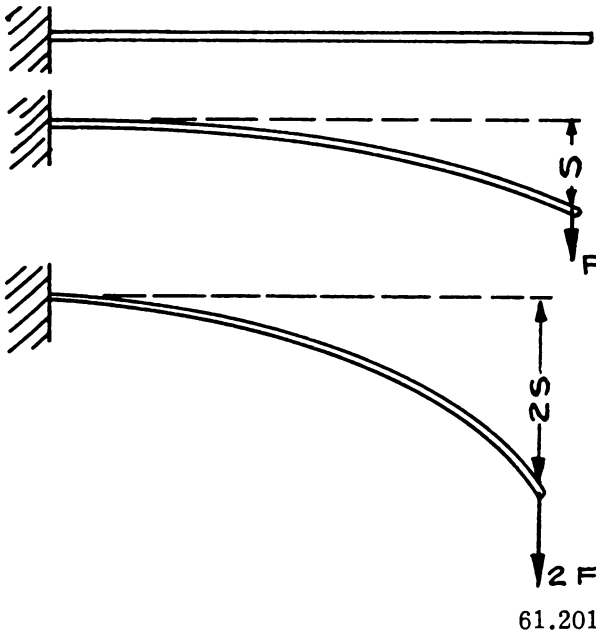


Figure 11-3.—Spring deflection.

is proportional to the force applied. The pointer does not deflect; therefore, the displacement of the beam with respect to the pointer, is measured directly on the scale. Hooke's Law, as applied to this situation, states that the deflection of the beam is proportional to the force applied. Since the length of the beam in figure 11-3 is fixed, the deflection may be converted and marked in units of torque.

This type wrench contains no frail mechanisms and is, therefore, a rugged and relatively accurate device. Since the beam is a fixed length, and the deflection of the wrench is a function of the force applied, it is imperative that when this wrench is used, the force be applied to the center or pivot point in the handle. If it is applied at any other point, the effective length of the wrench will change, and the indicated torque will be incorrect.

One disadvantage of this particular type wrench, as well as all flexible torque wrenches, is that since the beam is circular, the wrench is free to move not only in a plane parallel to the scale, but it will move equally well in other directions. This makes it tend to be unstable when applying torque.

Double Round Beam Wrench

An improved version of the round beam wrench, illustrated in figure 11-4, is the double

beam wrench. This wrench is referred to as double beam wrench because it has two beams connecting the head to the handle. The characteristics of this wrench are exactly the same as those of the single round beam, with the exception that the double beam minimizes deflection of the measuring element in any direction other than the direction that the torque is being applied.

The round beam and all flexible beam torque wrenches have a common disadvantage. The deflection of the beam is a function of the force applied and the length of the beam.

Since the torque indicated is a function of deflection, the point where the force is applied to the wrench is critical, and great care should be taken to ensure that the force is applied to the pivot point or center of the handle.

Flat Beam Wrench

Another type of flexible beam wrench utilizes a flat beam. The principle of operation of this wrench is exactly the same as the round beam wrench; only a flat beam connects the head to the handle of the wrench. The flat beam is considered a spring. As a force is applied to the handle the wrench bends, causing a deflection to occur between the pointer and the beam; this deflection is indicated in units of torque.

Tapered Beam Wrench

The most common type of flexible beam torque wrench in use today is the tapered beam wrench. This wrench is similar to the flat beam with the exception that the body of the wrench, which constitutes the spring, is tapered from the head to the handle with a larger cross sectional area at the head than at the handle.

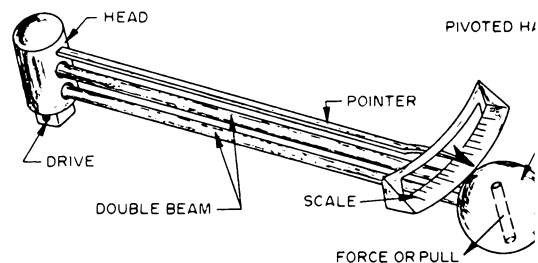
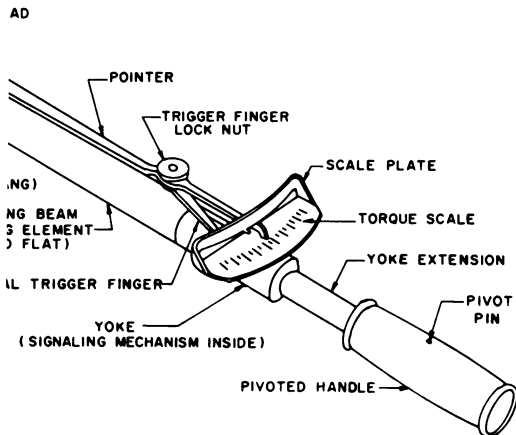


Figure 11-4.—Double round beam wrench.



5.9(61C)C

Figure 11-5.—Tapered beam wrench.

design provides a greater range for a beam size. Its principles of operation are the same as the flat beam. This instrument, with all flexible beam instruments, has a pivoted handle to ensure that the force is applied at the proper point. The operator must use caution in applying the force at the point to obtain accurate torque indications. A tapered beam wrench is shown in figure 11-5. Referring to figure 11-5, a head piece containing the drive square (tang) and fixed pointer is attached to one end of the beam. A trigger is attached to the other end of the beam. On the yoke is the torque scale handle. When provided, the signaling mechanism. If a signaling mechanism is included, a trigger is installed on the pointer. This can be used to trip the signaling mechanism at any pre-determined torque. The signal consists of a click and a sharp feel impulse in the handle. As a force is applied to the handle, the beam deflects with the scale. The pointer re-aligns, therefore a torque is indicated on the scale.

Another class of deflecting beam type wrench, described in the section which follows, is provided with a dial indicating gage instead of the pointer and torque scale arrangement.

FRAME TORQUE WRENCHES

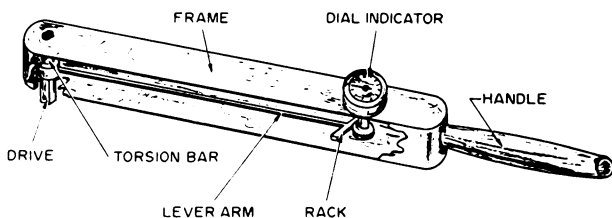
Another basic type of torque wrench is a rigid frame instrument. The rigid frame torque wrench utilizes a measuring element, enclosed in a frame. One basic type of rigid frame torque wrench is shown in figure 11-6.

This wrench is made up of two separate sections. The first section is composed of a dial indicator, wrench frame, and handle. These three items are rigidly connected together and act as an integral unit. The second section is made up of a drive assembly, lever arm, and rack. The two sections of this wrench are connected at one point, and one point only. A torsion bar, shown in figure 11-7, connects the drive assembly to the main frame of the wrench. The torsion bar behaves like a spring, only its displacement is rotational rather than linear.

Direct-Reading Torsion Bar Wrench

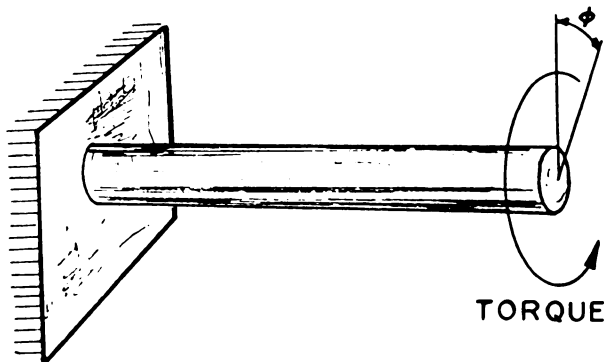
Figure 11-7 illustrates the operating characteristics of a torsion bar. Assuming that one end of the torsion bar is held rigid, and a twisting force or torque is applied to the other end, the free end of the torsion bar will twist or rotate through some angle. This angle of rotation is noted in figure 11-7 as Φ (phi).

If the torsion bar is operating within its elastic limits, the rotation of the free end of the bar, with respect to the fixed end, should



5.9(61C)D

Figure 11-6.—Basic rigid frame torque wrench.



61.202

Figure 11-7.—Torsion bar.

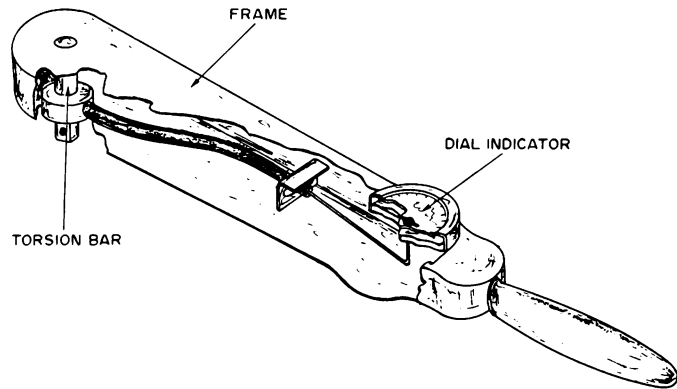
be a direct function of the torque applied. It is the angular displacement at one end of a torsion bar in a rigid frame wrench which allows it to measure torque. The range of torque which may be measured is a function of the cross sectional area, the material from which it is made, and the length of the torsion bar. In order to keep the size of the wrench relatively small, the length of the torsion bar is limited, and so the amount of angular deflection of the bar generated by a given torque is also small. This makes it necessary to mechanically amplify the torsion bar deflection to provide a readout with reasonable resolution.

Figure 11-8 is a cutaway of a slightly different but more typical rigid frame wrench. The torsion bar is connected at one end to the drive section, and at the other end to the frame of the wrench. The dial indicator actually measures the angular displacement between the frame of the wrench and the fastener to which torque is being applied. We might say that the frame of the wrench moves, whereas the drive section, lever arm, and rack assembly do not move. The pointer of the dial indicator is connected to a gear mated to the rack assembly. The proper selection of gear ratios between the rack and gear assembly obtains a mechanical amplification in the rotation of the dial indicator with respect to the rotation of the torsion bar itself. This displacement of the torsion bar is generally amplified approximately 450 times before the dial indicator readout.

Since the rotation of the torsion bar is a function of the torque applied to it from the frame of the wrench, it directly measures torque; thus, the length of the wrench is unimportant. It is generally accepted that with this type wrench the force can be applied at any point on the handle without appreciably affecting the readout.

Although the case of this type wrench is quite rigid, as a force is applied to the handle, there will be a slight bending of the case. If a force is applied first to one end of the handle and then to the other, it will be found that there are small deviations which exist in the indicated torque. The reason for this is that the case, although rigid, does bend somewhat. The errors introduced from the bending of the case are very small and generally can be neglected, but a good rule of thumb is to always grip this type wrench in the center of the handle.

Since this type wrench has moving parts, and the indicator is relatively sensitive, it will



5.9(61C)E

Figure 11-8.—Typical rigid bar wrench.

be found that its calibration will change with component wear of the moving parts. (This type wrench is adjustable in the field.)

All of the wrenches discussed to this point were direct reading. (Direct reading wrenches provide accuracies up to $\pm$ three percent IR or Indicated Reading.) The torque was indicated by some type of readout device, and it was up to the operator to visually observe the torque indicated and to remove the force when the required torque was reached. There is another group of rigid frame torque wrenches which do not provide a visual indication, but rather generate an audible signal. These wrenches are discussed in the sections which follow.

Audible Cam-Type Wrench

The audible cam-type wrench generally operates in such a manner that when a preset torque is achieved, the cam slips, allowing the wrench a few degrees of free rotation. At this point the operator senses a "give" in the handle of the wrench, which may or may not be accompanied by an audible click. This wrench provides no visual indication of torque, and only the "give" of the handle indicates to the operator that the proper torque has been reached. One type audible signal wrench is illustrated in figure 11-9.

CAUTION: After an audible signal wrench has reached the preset torque, and the cam has actuated, the wrench again becomes rigid. If the operator continues to apply a force after the wrench has actuated, damage to the wrench or fastener may occur.

ble Pivoted-Toggle Wrench

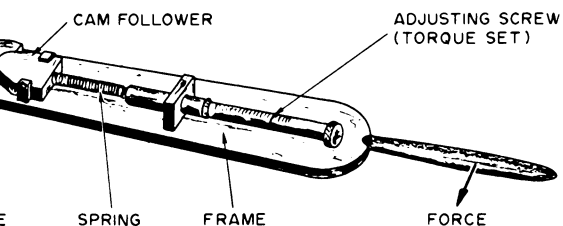
Another type of rigid frame audible signal wrench is shown in figure 11-10. This wrench is basically the same as a cam wrench with the exception that it uses a pivoted toggle instead of a cam to work against a spring in the handle.

When a preset torque is reached, the toggle connecting the load lever to the spring will breakaway, causing an audible signal to be felt in the handle of the wrench. This type wrench is adjustable over a considerable torque range and is preset by adjusting the handle of the wrench with respect to the frame. This adjustment causes the tension in the spring to increase or decrease, thereby requiring more or less torque to cause the toggle connecting link to pivot. This type wrench may operate in both right-hand and left-hand directions; however, it should be noted that some toggle type rigid frame wrenches are designed for use only in a right-hand direction. The operator should verify whether a particular wrench is designed to operate left-hand torque before it is used for any application. This type instrument provides accuracies to $\pm$ three percent of set torque.

One disadvantage of this type wrench is caused by the toggle bar which connects the handle head to the spring. This gives the wrench a configuration which is similar to a torque wrench with an extension placed on the end of the handle. Anytime an extension is placed on a torque wrench, the length of the instrument becomes extremely critical; therefore, when using a toggle action, rigid frame wrench, the force should always be applied to the center of the handle. If this is not done, the applied torque may be in error.

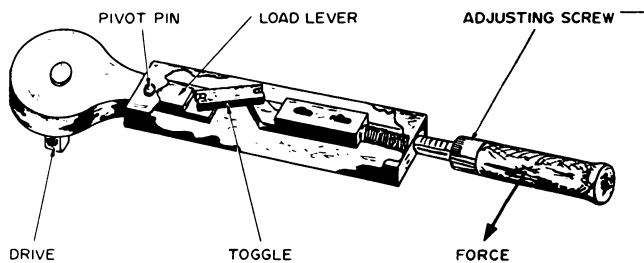
torque Screwdrivers

Another type of rigid frame audible wrench is called a torque screwdriver. Its principle of



5.9(61C)F

Figure 11-9.—Basic audible wrench.



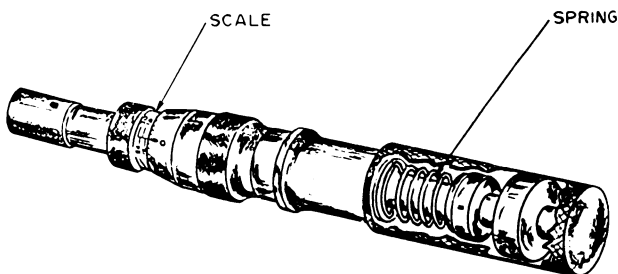
5.9(61C)G

Figure 11-10.—Toggle action audible signal wrench.

operation is similar to the previously discussed break type wrenches in that it uses a spring and cam, as illustrated in the cutaway view of figure 11-11.

This device also depends upon the tension in a spring to establish the torque point where it will release. These devices generally cover a reasonably wide torque range and are adjustable by turning the body of the wrench with reference to a torque scale engraved on the instrument itself. This action increases or decreases the tension on the spring, thereby establishing the preset torque required to overcome the force of the spring. Most instruments of this type may be readjusted in the field if they fail to meet calibration tolerance. This instrument is also accurate to $\pm$ three percent of set torque. Calibration and adjustment procedures are given later in the chapter.

When speaking of torque wrenches, there is one group of instruments which is rather specialized. These instruments are used for low torque applications. The first type is a low torque screwdriver, whose principle of operation is the same as the torque screwdriver just discussed; however, its range and size are much smaller (0-20 oz-in).



61.203.1

Figure 11-11.—Cutaway view of a torque screwdriver.

A second type instrument is called a torque watch. It operates on a principle slightly different from the torque screwdriver. First, it is not preset, but rather it is direct reading. Secondly, the pointer indications (torque) are a function of the rotation of a helical spring as it is wound or unwound. The amount of rotation of the spring is a direct function of the torque applied. The torque watch has a range of 0-10 oz-in with a tolerance of + five percent of full range.

ATTACHMENTS

An attachment enables connection of the torque wrench with the work. It may be any shape or form of work engaging member functioning coaxially with, and attachable to, the drive square of the wrench. The attachment does not affect the scale reading of the wrench. Common and special types of attachments are shown in figure 11-12.

TORQUE EXTENSIONS AND ADAPTORS

Many times a fastener that requires tightening is in a location that will not allow the use of a standard torque wrench. To apply torque to a blind bolt, a torque adaptor or extension often must be employed. Most torque adaptors or extensions are simply rigid frame wrenches which connect to the drive mechanism of a torque wrench and incorporate some angle with respect to the normal plane of the wrench. Examples of adaptors are shown in figure 11-13. A typical torque extension is illustrated in figure 11-14.

Using this illustration, let us investigate what occurs when an extension is used with a torque wrench. As shown in figure 11-14, we will define the normal length of a torque wrench as the distance between the center of the drive and the center of the handle. Let us call this length "1". Now consider the length of the extension from the center of the drive on the wrench to the end of the extension and call this distance "Δ1". The entire length of the assembly (1') from the center of the handle to the end of the extension is now the length of the wrench plus the length of the extension, or:

$$1' = 1 + \Delta 1$$

For purposes of explanation, let us further consider that the wrench illustrated is a flexible

beam type, although the discussion is true for any type wrench. Without the extension, the torque generated and indicated by this wrench is basically equal to the product of the force applied times the length of the wrench. Mathematically this may be written as:

$$L_i = F \times l$$

where: L_i = indicated torque

This expression is simply the basic equation for torque.

When an extension is attached to the end of the wrench, fastened rigidly and not free to move, it effectively becomes an integral part of the wrench itself. When a force is applied to the handle, the torque indicated by the wrench is still the product of the force applied times the nominal length of the wrench (1), but since the extension is rigid, the torque which is actually applied to the fastener is the product of the force applied to the handle and the entire length of the assembly. Therefore, we may say that the true torque applied with an extension is:

$$L_a = F \times (1 + \Delta 1)$$

where: L_a = applied torque

We now have two expressions for torque: the torque indicated by the wrench (L_i) and the actual torque applied to the fastener (L_a). The torque wrench will not directly read the actual torque applied to the fastener. To establish how much torque we are applying to a fastener when using an extension, we must develop some means of expressing the relationship between the indicated torque and the applied torque.

Let us set up a relationship between the indicated torque and the applied torque as follows:

$$\text{Since; } L_i = F \times l$$

$$\text{and: } L_a = F \times (1 + \Delta 1)$$

$$\text{then: } \frac{L_i}{L_a} = \frac{F \times l}{F \times (1 + \Delta 1)}$$

The force (F) in the numerator and the denominator cancels. We now have a new expression for the relationship between the indicated torque and applied torque for a wrench used with an extension. This expression is as follows:

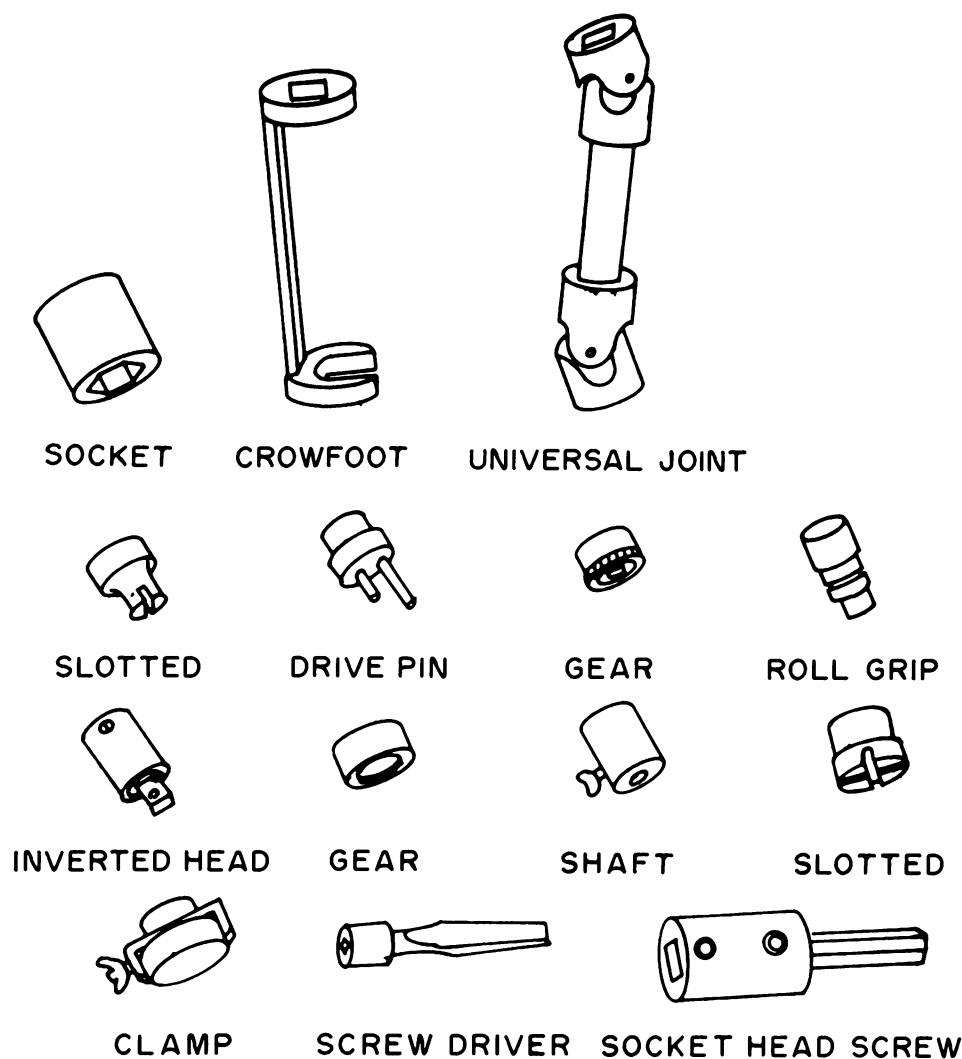


Figure 11-12.—Torque wrench attachments.

61.204

$$\frac{L_i}{L_a} = \frac{1}{1 + \Delta l}$$

We may now say that the ratio of the indicated torque to the applied torque is the same as the ratio of the length of the wrench to the length of the entire assembly with an extension.

When we use an extension, the torque wrench will only read the indicated torque.

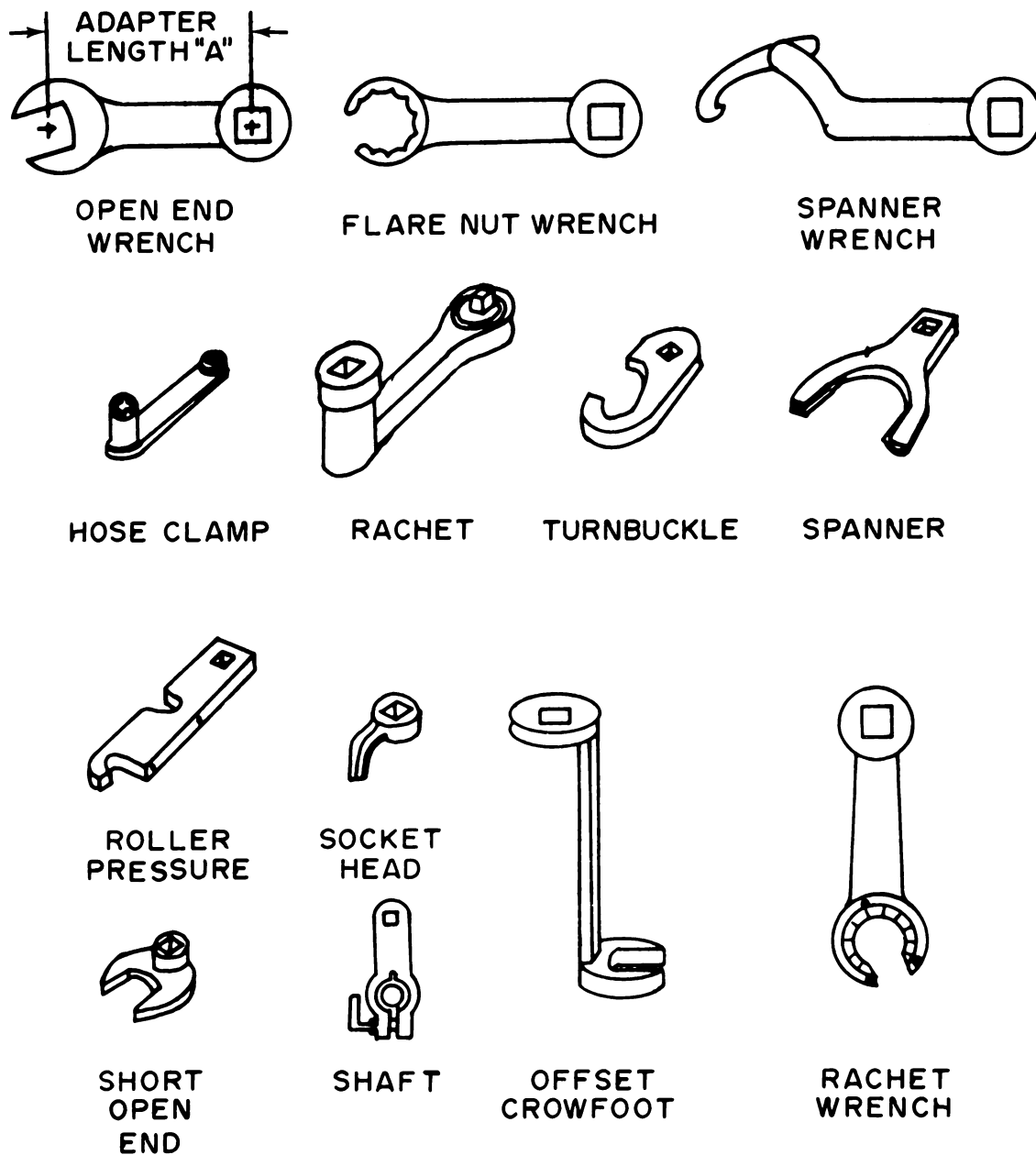
The applied torque can be computed by using the length of the extension and the indicated torque.

Thus, we may rewrite equation $\frac{L_i}{L_a} = \frac{1}{1 + \Delta l}$

in terms of the torque applied as follows:

$$L_a = L_i \left(\frac{1 + \Delta l}{1} \right)$$

This expression states that the actual torque applied is equal to the product of the torque indicated on the wrench and the ratio of the assembly length to the wrench length. Notice that in figure 11-4, the length (1) and the extension length (Δl) were all taken as the actual lengths parallel to the plane of the wrench. This is true for all extensions, regardless of their configuration.



61.205

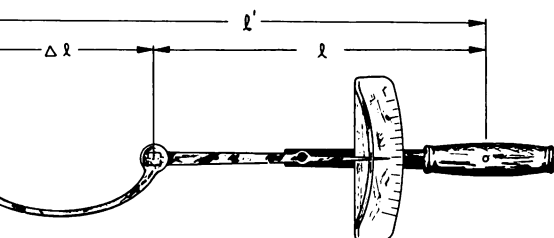
Figure 11-13.—Torque wrench adaptors.

If we have a wrench 12 inches long and an extension 6 inches long and apply a torque of 60 lb-in to a bolt, the indicated torque of the wrench will be (by using the appropriate formula) 40 lb-in.

Figure 11-15 illustrates two more types of extensions showing the initial length of the torque

wrench (1) and the total length of the torque wrench and extension ($1 + \Delta l$). Notice that all the lengths are always measured parallel to the plane of the wrench, and the actual length of the extension itself is not used.

The extension in a of figure 11-15 actually bends back toward the handle, and the length



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Figure 11-14.—Torque extension.

Δl) will be less than the original length

In this particular case, Δl is considered negative length, and $l + \Delta l$ is less than original length of the wrench. Therefore, actual torque applied with this type extension will be less than the indicated torque.

the length of the extension in (a) of figure 11-15 is 3 inches, and the wrench length is 18 inches, what will be the torque applied to a fastener when the torque wrench indicates 10 lb-in?

$$\text{Using the equation } L_a = L_i \frac{(l + \Delta l)}{l}$$

Substituting our values we get:

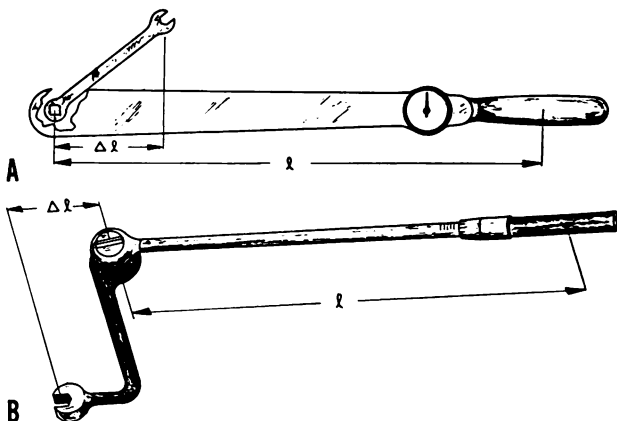
$$\begin{aligned} L_a &= 60 \text{ lb-in} \left[\frac{18 \text{ in} + (-3 \text{ in})}{18 \text{ in}} \right] \\ &= 60 \text{ lb-in} \left(\frac{15 \text{ in}}{18 \text{ in}} \right) \\ &= 60 \text{ lb-in} \left(\frac{5}{6} \right) \end{aligned}$$

$$L_a = 50 \text{ lb-in}$$

It does not matter with what type of wrench extension is used. Whether the wrench is a beam or a rigid frame, the relations derived for actual torque applied versus indicated torque are true for all type wrenches.

HANDLE AND TORQUE MULTIPLIERS

The "T" handle, illustrated with a conventional torque wrench in figure 11-16, is a handle to the length of the wrench lever extending in the opposite direction. (NOTE: In figure 11-16, A = length of the adaptor.) A universal relation is used between the drive square of the



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Figure 11-15.—Torque extensions, showing initial length (l) and total length (l + Δl).

wrench and the adaptor. This governs and equalizes the force applied to each of the handles by the operator. For the correct torque, multiply the scale reading by two.

In general, the maximum range of a one-man torque wrench is approximately 600 pound-feet. Torque applications beyond this should be made by using a torque multiplying device in conjunction with the torque wrench.

OPERATING TECHNIQUES FOR USING WRENCHES

Different types of torque wrenches and torque handles have different operating characteristics. It is not always easy to determine how a wrench will behave under given conditions. Some wrenches are not critical as to where the force is applied on the handle, others are. Some wrenches may tend to indicate erratically if the force is not properly applied to the handle. It is, therefore, good practice to follow certain prescribed techniques for the use of all wrenches. These techniques are:

- (1) The force should always be applied to the center of the handle of the torque instrument.
- (2) When applying torque, the force should be applied smoothly and uniformly without erratic jerking of the wrench.
- (3) It is preferable to pull on a wrench rather than push, as the application of force can be effected more smoothly when pulling.
- (4) The force applied to the handle of a wrench should always be applied parallel to the plane of action of the wrench.

(5) All threads should be clean before a fastener is installed. This will allow a smoother and more accurate torque to be realized.

When using a torque wrench it is not always possible to adhere to all of the prescribed techniques. However, you should always be conscious of what constitutes a good torque and realize that a careless torque application can jeopardize the safety of personnel.

TORQUE WRENCH CALIBRATION

To ensure that a torque wrench or torque handle is operating within prescribed tolerance limits, it must be calibrated periodically by an activity which has received instruments for calibration of wrenches. The instrument which is used to calibrate a torque wrench is called a torque tester. (Note: These instruments have been manufactured either by Sweeney Corporation or Torque Controls, Inc.) Torque testers are available which cover many ranges and utilize many principles of operation. The torque testers themselves, regardless of range or size, should be recalibrated every six months by returning to an installation that has facilities for performing this calibration. Once the testers are received, they should not be tampered with; any adjustment made without proper equipment will destroy the calibration of the instrument.

TORQUE TESTERS

The torque testers incorporate several interesting features which lend themselves to

total calibration of any torque handle. Each dial indicator has a friction type clutch. This clutch is of such a nature that it provides a memory device for the tester. As a torque is applied to the tester from the wrench under test, the indicator on the tester will hold the indication of the highest torque applied until such time as the dial indicator is reset. This is a desirable factor when calibrating break-type wrenches, as after the wrench "breaks" the torque tester will indicate the point at which the highest torque was applied prior to the release of the wrench.

The testers also allow the calibration of any wrench in either a right or left-hand direction. All that is required to calibrate in a right or left-hand direction is to reverse the dial indicator on top of the tester so that it is facing the right or left-hand input shaft. This is readily accomplished by simple loosening the two setscrews which hold the dial indicator to the tester, removing and reversing the indicator, and then retightening the setscrews.

Prior to its use, each tester should be prestressed to full scale once and then zeroed before a torque wrench is attached. This zeroing process is very important and accomplished by firmly depressing the reset button on top of the dial indicator and then releasing it slowly and smoothly. This zeroing technique establishes the normal rest point of the dial indicator with respect to the measuring element in the tester.

CAUTION: WHEN PRESSURE IS REMOVED FROM THE RESET BUTTON, IT MUST BE DONE SLOWLY AND SMOOTHLY.

If the operator removes his finger too quickly, the inertia of the dial indicator will

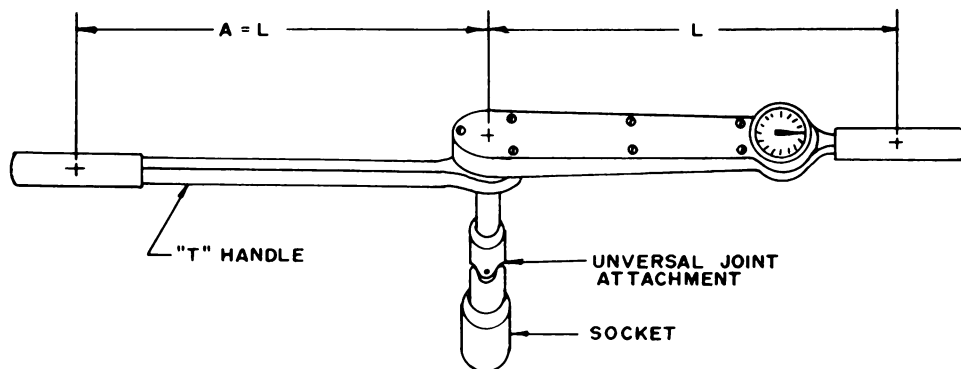


Figure 11-16.—Use of "T" handle with conventional torque wrench.

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carry the pointer above the normal zero position, and the memory device in the dial indicator will hold it at this false indication.

After the instrument is zeroed, if the pointer position does not agree with the zero indication on the scale of the dial indicator, the indicator scale is rotated until the zero scale indication and the pointer agree. This is accomplished by loosening the thumb screw on the face of the dial indicator as shown in figure 11-17, and rotating the scale until the zero indication on the dial indicator agrees with the pointer position. The reset button should be depressed again and released to ensure that zero can be repeated. If the new zero point does not agree with the initial zero point, it is probably due to an improper release technique by the operator. The proper technique of zeroing can be achieved by experience. Each time torque is removed from the tester or prior to each use, the dial indicator should be checked for zero. The zeroing of the tester should never be attempted with the torque wrench under calibration engaged on the unit. The wrench under test should always be removed.

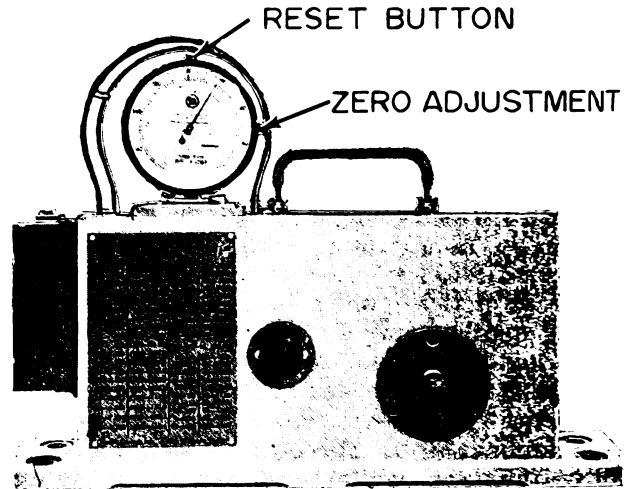
The Torque Controls Inc. torque testers, commonly used by the Navy have three basic units. The low range torque tester has a range from 0 to 500 lb-in. The next tester has a range of from 0 to 2,000 lb-in, and the high range tester covers the range from 0 to 1,000 lb-ft. These three testers should provide almost 100 percent capability for the calibration of torque wrenches.

A typical tester is shown in figure 11-18. This tester, shown in figure 11-17, whose range is 0 to 1,000 pound-feet (lb-ft), has one drive shaft. The dial indicator is a ten turn type one scale. Each revolution of the pointer is equal to 100 pound-feet. The drive shaft attachments are a 3/4-inch socket and one-inch socket.

The two lower range instruments are actually two torque calibrators in one package. The low range instrument provides calibration in two steps from 0 to 100 oz-in and from 0 to 500 oz-in. The indicator reads directly in units of torque but has two scales. The scale to be read is determined by which input shaft is used for the calibration of a torque wrench. Each indicator is a 10-turn type. If we were calibrating in the range of 0 to 100 oz-in, the indicator would rotate through ten complete revolutions to indicate full scale or 100 oz-in. This means that each revolution is equal to 10 oz-in. If the calibration were from 0 to 500 oz-in,

each revolution would be equivalent to 50 oz-in.

The 0-2,000 lb-in unit also has two ranges. The low range is from 0 to 250 lb-in, and the high range from 0 to 2,000 lb-in.



61.206.1

Figure 11-17.—Zeroing adjustments.

A schematic illustration showing construction of a 0-2,000 pound-inch (lb-in) torque tester is shown in figure 11-19.

This tester has only one drive shaft, but two ranges. Different ranges may be selected by the range selector switch for positions on Scales "A" and "B". In scale A position the range is from 0 to 2,000 lb-in, and in scale B position, the range is from 0 to 250 lb-in. (On scale A, each pointer revolution is equal to 200 lb-in, and on scale B, each pointer revolution is equal to 25 lb-in.) The drive shaft attachments are three sockets (1/4-inch, 3/8-inch, and 1/2-inch).

One of the interesting features of a typical dual range unit is the use of a dial indicator, which reads directly in units of torque and makes 10 complete revolutions over each range, thus providing very high resolution. The input (test) shaft goes completely through the tester. If a wrench is to be calibrated in one direction, it is attached to the input shaft on one side of the tester. If it is to be calibrated in the other direction, it is attached to the same shaft on the other side of the tester. This feature allows for the calibration of a wrench in either clockwise or counterclockwise direction, while the

tester components only move in one direction.

Figure 11-20 clearly illustrates the working parts of a dual range torque tester. As torque is applied from a wrench to the INPUT (calibration) shaft A, it imposes a force at the end of the beam at point B. Since the input shaft (A) and the beam are an integral part, the force generated at the end of the beam at point B is a direct

function of the torque applied. If the torque applied is doubled, the force acting upward at the end of the beam is doubled. This upward force is then transmitted to the end of spring C. The spring is of such a nature that the deflection (D), or change in position at the end of the spring, is a direct function of the force imposed at the end of the beam. This force is, in reality, a measure of the torque applied at the

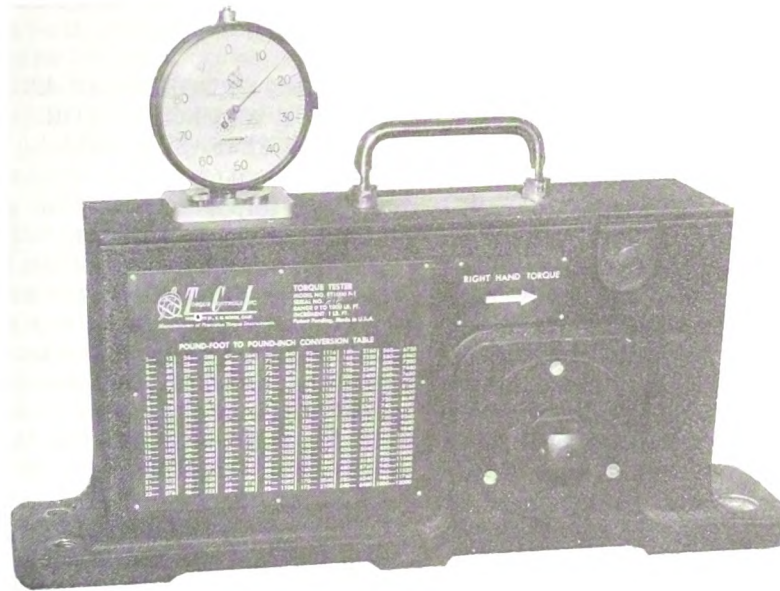


Figure 11-18.—Torque wrench calibrator.

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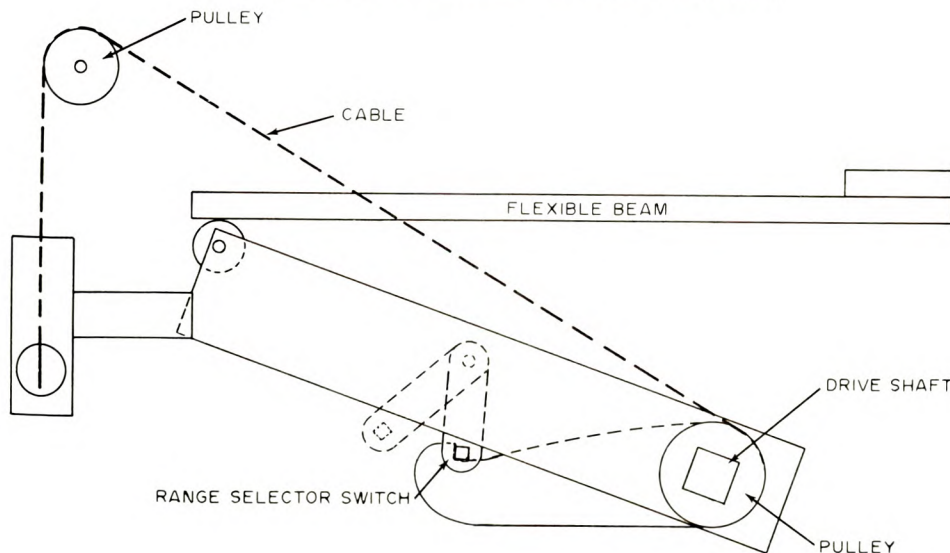
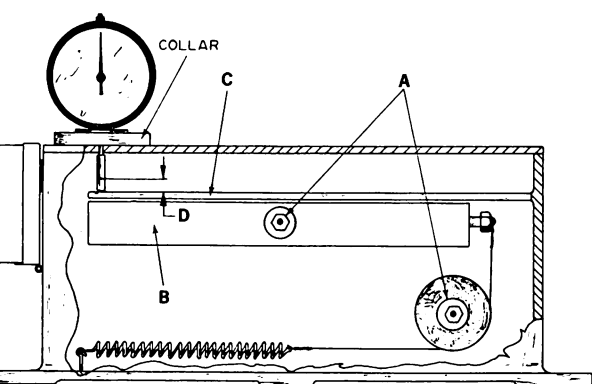


Figure 11-19.—0 to 2,000 pound-inch torque tester.

61.207.1



61.207.2

Figure 11-20.—Dual range torque tester.

input shaft; therefore, the deflection (D) or change of position of the beam is directly related to the torque applied. If we use a dial indicator to measure the displacement of the beam, and once the system constant or ratio of torque to force is established, we can then measure the actual torque applied at the input shaft in terms of the displacement of the end of the spring. The dial indicator, therefore, indicates torque directly as a function of the displacement of the end of the spring. (This technique is used in all Torque Controls, Inc. torque testers.)

The dial indicator is connected to the tester by means of a movable collar. This collar allows the relative position of the dial indicator on the spring to be changed. Since the displacement (D) at different points on the spring is different for a given torque, the collar allows the dial indicator, and thus the torque indication, to be adjusted when the tester itself is calibrated. (Note: The collar should never be moved between calibrations.)

CARE OF TORQUE WRENCHES

In the deflecting beam type wrench, the beam portion is the sensing device. It should not be marked, etched, or scratched with part numbers, tool numbers, or any other markings.

As far as the pointer of a deflecting beam type wrench is concerned, you should be familiar with the adjustments for zero setting and floating the pointer.

For Zero Setting, the pointer tip should intersect the zero mark on the scale when the tool lies at rest. Make minor adjustment by bending the pointer tip with pliers. Larger

adjustment may be made by springing the entire pointer. Hold the pointer at the head end of the wrench where it is welded to prevent breaking it off.

As far as Floating the Pointer is concerned, this is an adjustment to prevent the pointer from riding on the scale plate or contracting the beam. Lock the head end of the wrench in a vise to prevent breaking the pointer out of the head, and slide a knife or wedge between the pointer and the beam. This will tend to lift the pointer, clearing it.

LOCKING PROCEDURES AND TORQUE WRENCHES FOR THREADED FASTENERS

The importance of the proper locking of fasteners such as nuts, bolts, screws, plugs, and hose fittings cannot be overemphasized in naval use. Many shipboard machinery casualties now result because a locking device was not installed or was installed incorrectly at time of last assembly. Major consequential damage has occurred many times because of a loose bolt or nut in the system. On land, fasteners are subject to the loosening effects of machinery vibration, and thermal expansion and contraction. Even normal daily temperature changes make a measurable difference in the clamping forces of nuts and bolts. The heat produced by the machinery increases these differences. At sea, such loosening effects are aggravated by stresses caused by the roll and pitch of the ship. The vibrations transmitted by the less firm foundation of the ship's hull are intensified by the quantities of various types of machinery found on board. In addition, shock loads are encountered through operation in heavy seas, from firing off ship's guns and, in combat, from near misses.

The selection of the proper locking device to be used must be made by the equipment designer, and can be found in the parts lists, drawing, and/or equipment manual.

Proper torque aids the locking of all types of thread locking fasteners. After tightening, nuts or bolts are held by the static friction of the nut and bolt head against the surface of the items being held together and the friction on the threads of the nut and bolt against each other. This friction is caused by the clamping force created by a slight stretching of the bolt when the nut is tightened. The metal, which is slightly elastic, will pull back towards its original

dimensions creating large clamping forces. Excessive tightening will cause the metal to pass its limit of elasticity and result in a permanent stretch. Because of this effect, overtorquing will actually result in lesser frictional forces and probably bolt loosening. In addition, the over-stretched bolt is weaker and more likely to break from vibration and thermal expansion. Undertorquing also results in low frictional forces and the likelihood of loosening. Since burrs and poor mating surfaces of threads can effect the torque materially, all threads should be inspected for cleanliness and burrs before torquing.

Torque tables should be used to check the torque for a specific metal because different metals have their own limits of elasticity. These tables can be found either in manufacturers' technical manuals or chapter 9090 of NavShips Technical Manual. NavShips drawings should also be consulted, when required.

Both the nut and the bolt threads should be evenly and lightly coated with a light lubricant or antiseize compound; this compound should be used whenever a nut or bolt is installed in a high temperature area. (Note: As some antiseize compounds become corrosive under heat, always use the compound recommended in the applicable manuals. Remember that graphite attacks stainless steel and molybdenum corrodes silver.)

Any fasteners with damaged threads should be discarded. Failure to comply with such pretorquing requirements results in an inaccurate torque measurement. When studs or cap screws are to be torqued into blind holes, the holes should be clean and excessive lubricant or antiseize compound removed. Pressure transmitted by excessive lubricants or other materials at the bottom of blind holes can crack metal parts.

All bolts in an assembly should be installed and snugged up before torquing. Final torque to all bolts in any one flange or assembly should be performed by one person. When using a torque wrench or other method torque specified (such as measurement of the length of the bolt before and after installation to get a predetermined stretch or snugging up the nut and then turning an added half to three quarter turn), the only way to ensure an even torque is to allow only one person to do the measurement and final turn.

Torque should be applied slowly and evenly until the specified torque is reached. Torquing should be accomplished in accordance with manufacturer's instructions for the specific unit.

As mentioned previously, the torque wrench should be calibrated frequently. The flat and round beam wrenches normally give true readings as long as their pointers indicate zero and the drive heads are tight. Because these wrenches can be kept in calibration, they are recommended for shipboard use.

Other type torque wrenches that indicate by means of a dial indicator, or by releasing or signaling when a preset load is reached are more sensitive to shock and dirt; therefore, they should be recalibrated whenever possible. A minimum of 30 days between calibrations is recommended. Never check one torque against another.

Additional information on locking procedures and torque wrenches for threaded fasteners can be obtained from chapter 9090 of NavShips Technical Manual. Information dealing with assembly, reassembly, cleaning, and lubrication of torque indicating devices can be obtained from manufacturer's technical manuals for specific equipment.

TORQUE CALIBRATION ACCURACY, STANDARDS, AND TOLERANCES

The torque testers used by the Navy are generally accurate to within one percent, or one scale graduation, whichever is greater, of the indicated value. To obtain optimum accuracy from the tester, the following factors must be considered and/or observed:

1. Always use the lowest span which will accommodate the wrench under test.
2. If you are calibrating a wrench which reads from 0 to 200 lb-in, do not calibrate it by using the 0 to 2,000 lb-in range; use the 0 to 250 lb-in range.
3. It may be advantageous to use two testers where it is desired to maintain a four to one ratio of accuracy of the standard over the test instrument. If the range of the wrench is from 0 to 300 lb-ft, you will use two torque testers; the 0 to 2,000 lb-in and the 0 to 1,000 lb-ft testers.

Calibration standards must be supplied with a certification traceable to the National Bureau of Standards. In accordance with the recommended calibration standards, you should be familiar with the following facts:

1. Primary torque standards consist of a balance arm with a radius segment upon which weights can be hung.

2. The radius segment should consist of a balance arm so that the weight will always be applied to a point on the arc at 90° to the horizontal line through the center of the arc.

3. The primary standards used in calibrating the torque tester must be at least four times as accurate as the testers.

Torque wrench tolerances specified in the Federal specifications are as follows:

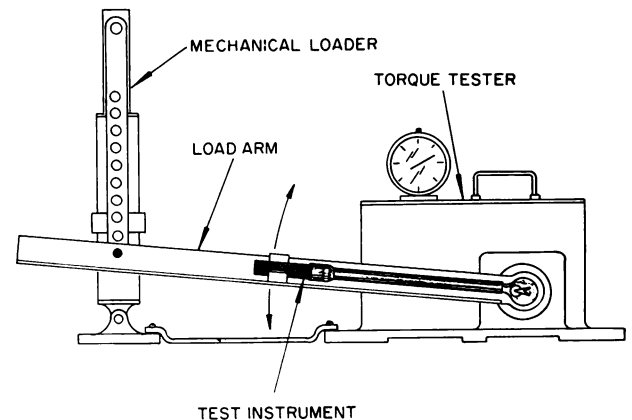
From	Up to But Not Including	Tolerance Within
0	20% of the span	±7% of indicated value
20	80% of the span	±4% of indicated value
80	100% of the span	±5% of indicated value

CALIBRATION PROCEDURE FOR TORQUE WRENCHES

To calibrate a torque handle, or wrench, the tester is first zeroed and then the torque handle under test is connected to the appropriate shaft of the appropriate tester. On low range torque handles, the operator may use his hand to apply a force on the torque handle. However, on high range torque wrenches a mechanical load (fig. 11-21), provided for calibration of these wrenches, should be used.

All torque handles should be calibrated at approximately five points distributed over the range of the wrench under test. If a torque handle had a range of from 0 to 250 lb-in, the operator might select the calibration points of 25, 50, 100, 150, 200, and 250 lb-in. The points of calibration are totally arbitrary but should cover the entire range of the wrench under test. The torque handle under test should always be set to a cardinal point and the torque tester read. This practice allows the high resolution of the torque tester to be used.

Torque handles are always calibrated in an increasing direction from the low end to the high, never in a decreasing direction. When calibrating a flexible beam wrench, a force would be exerted on the handle until the wrench indicates the first point chosen. At that time the dial indicator on the tester is read and com-



61.208

Figure 11-21.—Mechanical loader.

pared with the indication on the torque handle. The next higher point would then be set on the wrench and again the tester indication would be noted and compared with the reading.

When calibrating a rigid frame wrench which incorporates an audible signal, extreme caution must be exercised that the break point of the wrench is properly established. If a force is applied too rapidly to a break type wrench, when the wrench arrives at the preset torque and breaks it will cause a snapping action which may be transmitted to the tester, causing the dial indicator to jump. Again the memory of the dial indicator will hold it at this incorrect reading, and thus generates an apparent error between the wrench and the tester. The break-type wrench should be calibrated using an extremely smooth, slow motion until the wrench breaks smoothly without causing any noticeable snapping action. At this time the operator may be reasonably confident that the indicated torque on the tester is the actual break point of the wrench. Each calibration point that is chosen on the break-type wrench should be repeated concurrently three or four times. After the readings are taken, the operator should choose what he considers a good average reading and record this as the torque is applied.

Detailed information concerning calibration of torque handles can be obtained from Instrument Calibration Procedure, NavWebs 17-20 MU07. It should be noted, however, that a recommended calibration procedure for torque wrenches, using a typical torque controls tester, is given in the paragraphs which follow.

The recommended calibration procedure for torque wrenches, using a typical torque controls torque tester, is as follows:

1. Test Instrument Inspection
 - a. Repair obvious defects.
 - b. Clean instrument, if necessary.
2. Exercise Standard and Test Instrument (right-hand torque)
 - a. Attach the test instrument to the standard.
 - b. Apply force to the handle of the test instrument.
 - c. Increase the force until the test instrument indicates full scale.
 - d. Release the force until the test instrument indicates zero.
 - e. Exercise both the test instrument and the standard to full scale of the test instrument two more times.
3. Establish Rest Point
 - a. Remove the test instrument from the standard.
 - b. Depress the reset button on the top of the dial indicator firmly.
 - c. Release the button slowly and smoothly.

(NOTE: If the 0-100 ounce-inch standard is being used, a 5 ounce calibrating bar must be attached to the position "B" input shaft in a horizontal position. The bar puts a slight load on the tester, eliminating the small errors that exist at the zero position. The scale "B" is then rotated until the 5-ounce-inch indication agrees with the main pointer.)
4. Zero Standard
 - a. Loosen the thumb lock screw on the right side of the dial indicator.
 - b. Rotate the scale until the zero indication on the dial agrees with the pointer position.
 - c. Tighten the thumb lock screw.
 - d. If the 5-ounce calibrating bar is used for establishing the rest point, the 0-100 ounce-inch scale is then rotated until the 5-ounce-inch indication agrees with the pointer.
5. Zero Test Instrument
 - a. Align the pointer and the zero indication on the dial for the right hand torque.
 - b. Make certain that the zero indication is for the right-hand torque.
6. Linearity Test, Right-Hand Torque (up-scale)
 - a. Select five approximately equally spaced nominal values covering the range of the test instrument.
 - b. Record the values in increasing order.

- c. Attach the test instrument to the standard.
- d. Apply force to the test instrument until the first nominal value is indicated by the pointer on the test instrument.
- e. The nominal value must be approached in the direction of increasing force.
- f. If the pointer on the test instrument moves past the nominal selected, decrease the force and repeat step "d."
- g. Depress the reset button, on the top of the dial indicator, firmly and then release the button slowly and smoothly.
- h. Record the standard's indication.
- i. Repeat steps "d" through "h" for each of the remaining calibration points in the increasing order listed for this test.

For left-hand torque, repeat steps 2 through 6 of the calibration procedure, except for information concerning right hand torque.

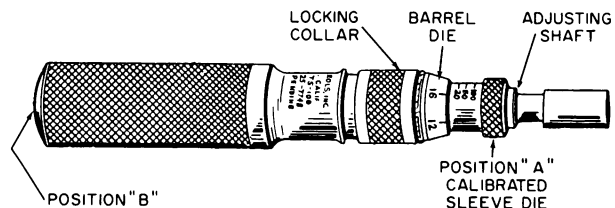
On non-adjustable torque wrenches, repeat the calibration. Then average the recorded values and verify that they are within tolerance.

On adjustable torque wrenches, verify that the values recorded are within tolerance; if not, take corrective action and repeat the calibration.

Apply the appropriate calibration label tag in a conspicuous position on the test instrument after both calibration runs have been made.

CALIBRATION PROCEDURE FOR TORQUE SCREWDRIVERS

As an Instrumentman, you will be required to calibrate and adjust torque screwdrivers. Using a typical torque screwdriver, illustrated in figure 11-22 and similar to those manufactured by Torque Controls, Inc., the recommended calibration procedures are given in the discussion which follows.



61.203.2
Figure 11-22.—Full view of torque screwdriver.

To perform the simple or quick calibration method, proceed as follows:

Before breaking fusible alloy seals at positions "A" and "B", test check the torque screwdriver on an approved torque tester at the minimum reading, and also at the maximum reading. If the unit is out of tolerance and uniformly low or uniformly high at both readings, it is probable that a slight change of the position "B" setting will correct this condition. This corrective action should only be attempted at the maximum end of the range. Therefore, remove only the position "B" seal and turn the adjusting nylock setscrew slightly in a clockwise direction to bring the reading up, or in a counterclockwise direction to bring the reading down.

Before sealing, check out the unit on an approved torque tester. Break over torque at least four times, or, until it is determined that the unit is operating on the high side of the highest limit. When this is accomplished, and before replacing the "B" position seal, test the unit at the low end of the scale. If these readings are on the high side of the tolerance, the unit can now be sealed and placed back in service.

CAUTION: Do not attempt to correct a deficiency in the low scale by adjusting from the "B" position alone.

As far as the Major Calibration Method is concerned, major calibration is accomplished by first adjusting the low scale, therefore, proceed as follows:

1. Unseal the unit at both positions "A" and "B".
2. Loosen the setscrew at positions "A." DO NOT, at this time, loosen the screw at position "B".
3. Slide back the calibrated sleeve die, thus uncovering the adjusting shaft.

4. With a thumb and forefinger, turn only the adjusting shaft slightly to the right to increase torque, to the left to decrease torque, disregarding the relative position of the sleeve die to the markings on the barrel die.

5. Before tightening down the setscrew on the sleeve die, test check the unit on an approved torque tester at the low scale reading only.

6. Assured that you are now breaking the unit on the high side of the allowable tolerance for the low torque range and without disturbing the adjusting shaft, slide the sleeve die forward and bisect the lowest crossline on the sleeve die.

7. Lock the setscrew on the sleeve die securely to the adjusting shaft.

8. Adjust the high range in the manner explained under the instructions given for the "Simple or Quick Calibration Method."

9. When the readings on an approved torque tester show the unit to be operating within the tolerance on the high side of the low range and within tolerance on the high side of the high range, seal the unit at both positions "A" and "B" and place the unit back in service.

In order to promote a longer tool life, the unit must always be sealed when in use. Never use an unsealed unit. The sealing compound should be a fusible alloy (melting point 165 to 200 degrees). The sealing compound should be removed by using a light soldering iron. When not in use, the unit should be set to the low end of the range. If dropped, the unit should be checked out on an approved torque tester before using. The drive shaft must always be free in both a longitudinal and rotating direction, before and after breaking through torque. This play in the shaft is important to the proper functioning of the unit.

CHAPTER 12

WATCH AND CLOCK MECHANISMS

This chapter discusses timepieces used by the Navy, the mechanism of a watch, the tools and equipment used in watch repair, and the major components of a clock. As an IM3 or an IM2, you are not expected to be an expert jeweler, but there are certain duties connected with this work which you must be able to do before you can advance in rate. You must be able to use a jeweler's lathe, for example, and also demagnetizing and instrument-cleaning machines. You must know what tools are used by a jeweler and how to care for them.

In addition to the nomenclature, function of parts, and definition of technical terms used in watch and clock repair, you must know how to disassemble, clean, lubricate, and reassemble clock main and time trains. (Watch and clock maintenance is discussed in chapter 13 of this rate training manual.)

Timepieces generally used in the Navy are: (1) chronometers, (2) regular and comparison watches, (3) clocks, and (4) the Elgin timer. A brief discussion of each follows.

The most accurate timepiece used by the Navy is a chronometer, or a chronometer watch. The chronometer is a precision instrument used for navigational purposes only. Because this timepiece must be almost perfect in accuracy, special scientific equipment is essential for checking it upon completion of repair work. For this reason, only designated naval repair activities with proper tools and equipment have the responsibility for servicing it. Your instrument shop aboard ship will not service chronometers.

The standard Navy comparison watch is a 17-jewel Hamilton; a precision timepiece. The Quartermaster uses it for conveying chronometer time to clocks located at various ship's stations. The instrument shop is responsible for cleaning and repairing this watch, and any other similar ones. In addition, Instrumentmen may

be required to repair various types of watches, as the occasion demands.

Navy clocks vary in size and type in accordance with needs. Most of them have 11 jewels. Cases are made of metal or phenolic materials. Some have striking movements. The 6-inch and 8 1/2-inch dial sizes are used for most purposes. Two typical clocks used at ship's stations are shown in figure 12-1. At least once a week the Quartermaster checks all clocks with a standard comparing watch. He winds the clocks at this time and resets them when necessary.

An Elgin timer is a standard Elgin pocket watch with a continuous running, single-action, stop-control mechanism. Some types have 7 jewels and others have 15 jewels. It has a sweep second hand and a minute registering hand, but no hour hand. You can start the second hand by depressing the stem, stop it by depressing the stem a second time, and return it to zero by depressing the stem a third time. An Elgin timer is illustrated in figure 12-2. Elgin timers are used for accurate timing evaluations aboard ship such as fire control, drills, and general timing purposes.

MAJOR COMPONENTS OF WATCHES

This discussion of the mechanism of a watch is not exhaustive, but it will give you a general idea as to why a watch keeps time. Actually, the movement of a watch is not complicated, but each part must be made correctly and function properly in order for the watch to keep good time. The first thing you need to know about a watch is what each part in the mechanism is, why it is necessary, and how it operates. You should know how to disassemble a watch and how to care for all the parts; and you should know how to clean and reassemble the entire works.



CHELSEA 8-1/2"
TYPE B MECHANICAL
CLOCK IN PHENOLIC CASE



CHELSEA 6"
TYPE A MECHANICAL
CLOCK IN PHENOLIC CASE

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Figure 12-1.—Navy mechanical clocks.

This chapter covers some of the basis principles of the repair of a conventional watch.

A conventional watch has four major parts, or mechanisms: (1) driving mechanism, (2) transmitting mechanism, (3) controlling mechanism,

and (4) indicating mechanism. Study figure 12-3, which shows most of the four major parts in their operating positions. Refer to this illustration, as necessary, while studying about the mechanism.

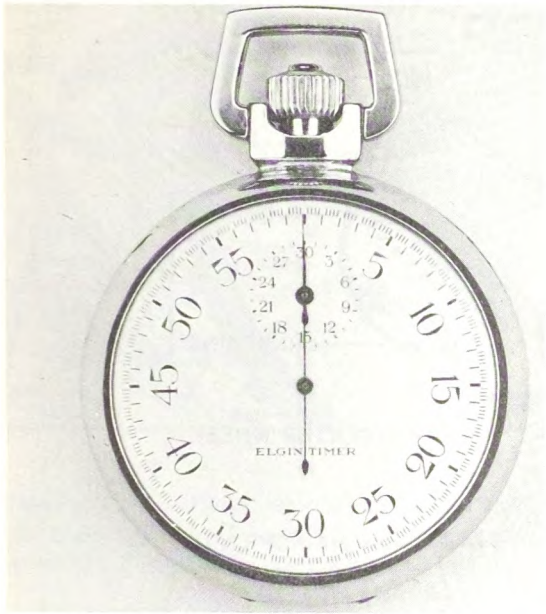


Figure 12-2.—Standard Elgin timer stop watch. 61.68

DRIVING MECHANISM

The driving mechanism consists of the main-spring coiled around an arbor within a barrel. The mainspring is a coiled ribbon of steel. When wound and placed in the barrel, the inside end must be fastened to the catch on the barrel arbor and the other end fastened to a catch on the inside of the barrel. When the spring is wound, energy is stored up for running the train and the escape units. A ratchet and click (pawl), shown in figure 12-4, prevent the mainspring from unwinding. Teeth on the outer edge of the main-spring barrel mesh with a small gear wheel on the pinion of the center wheel and drive the transmitting mechanism (the train).

The mainspring of a conventional watch rotates once every 8 hours. The barrel normally turns five times before the mainspring completely uncoils. This means that the watch runs 40 hours with one winding.

TRANSMITTING MECHANISM

The transmitting mechanism consists of the center wheel and pinion, third wheel and pinion, fourth wheel pinion, and the escape wheel and

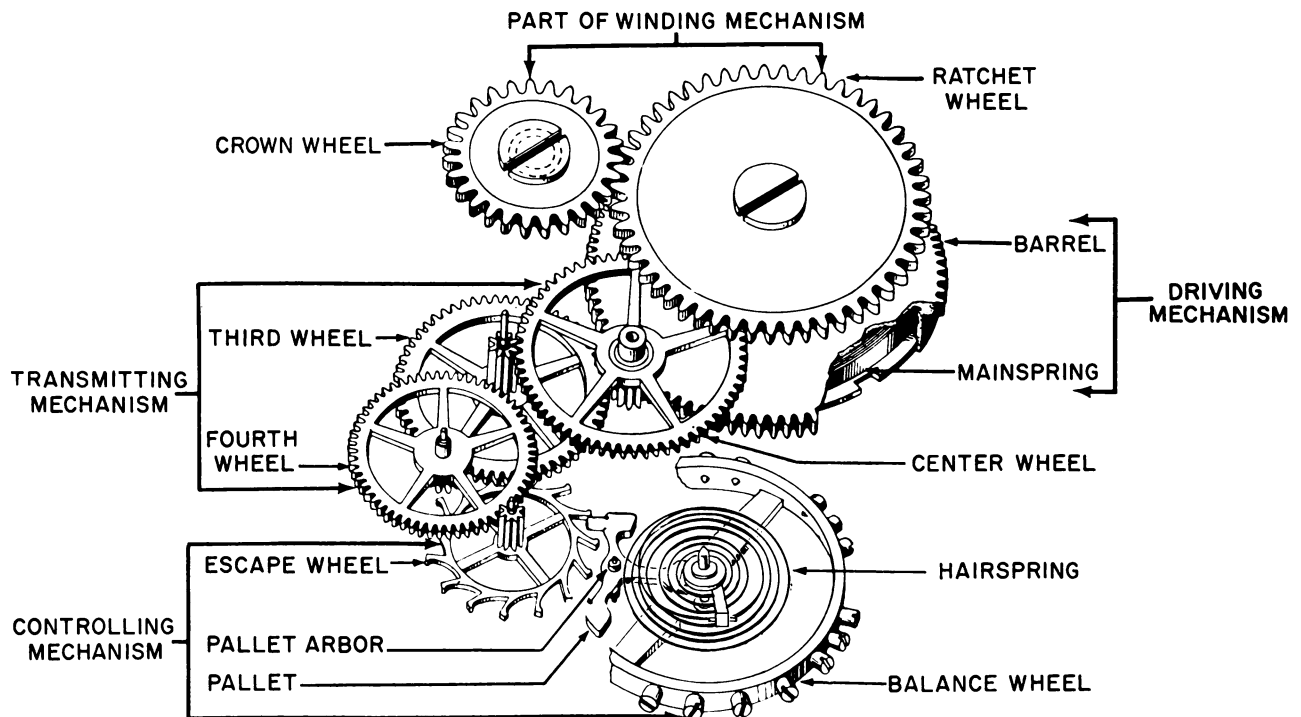
pinion (fig. 12-3). It also supports the hand of the watch, which are part of the indicating mechanism. The center wheel arbor turns once per hour, the third wheel arbor turns $7\frac{1}{2}$ times per hour, and the fourth wheel arbor turns 60 times per hour. The escape wheel in the controlling unit mechanism turns 10 times per minute, or 600 times per hour. Since it has 15 teeth, 9000 escape wheel teeth pass a given point in an hour (600×15).

You know that a watch generally has jewels, but you may not know how many jewels are used or why they are necessary. The function of jewels is to reduce friction and wear on pivots and bearings in watches, to ensure greater accuracy and longer life of the watch. The best watches have 17 or more jewels. Navy stop watches have 7 and 15 jewels. A railroad watch, for example, must have 21 jewels to warrant such a classification. Jewels are of great importance in the controlling and transmitting mechanisms.

At one time most watch jewels were made from diamonds and other precious stones. Now, however, they are generally made from synthetic stones. They are ground with curved or flat surfaces, but the curved surface is best for retaining oil. After a jewel is put in place at each end of the balance staff, it is capped with an endstone with about 0.02 mm clearance from the jewel. When oil is put in the convex portion of the jewel (top), it is held in position around the pivot by capillary attraction until it evaporates, some 12 to 18 months later. (Capillary attraction holds the oil at the point of contact of the pivot in the jewel hole or with the endstone, where the curved portion of the bottom of the jewel comes in closest contact with the endstone.) Check the position of some jewels in the transmitting mechanism (fig. 12-4).

The controlling mechanism is the most vital part of a watch. It is the part which so regulates the movement of the watch that it keeps time. There are two units in this mechanism: (1) escapement, and (2) balance and hairspring. Turn back to figure 12-3 and take another look at the position of the escape wheel, the pallet, the balance wheel, and the hairspring. Then study 12-5, which shows an enlarged view of the escape wheel, pallet and fork, and the balance wheel.

The escapement in the controlling mechanism is a device which changes the rotary motion of the escape wheel to a back-and-forth motion of the pallet. The pallet, rocking on the pallet arbor



61.69X

Figure 12-3.—Major units of a watch in their operating positions.

(fig. 12-5), give the balance wheel an impulse and causes it to oscillate.

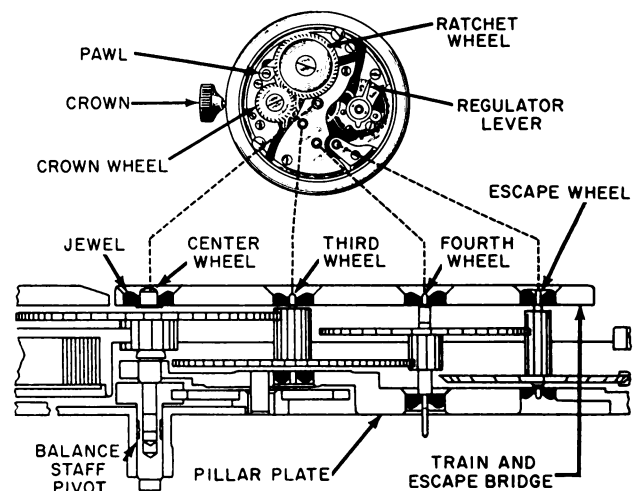
The balance unit performs the actual time-keeping and, for this reason, is called the brain of a watch.

Most balance wheels used in present-day watches have rims of Elinvar, a nickel-steel chromium alloy almost insensitive to temperature changes. This feature reduces the amount of adjustment required on the balance wheel, and helps to maintain accuracy.

A detached lever escapement consists of a fork and pallet (fig. 12-5). When energy is carried by the train to the escape wheel, it turns this wheel in the direction indicated by the arrow in figure 12-5. As the pallet receives energy from the escape wheel and rocks back and forth on the pallet arbor, the pallet fork moves the roller jewel. The roller jewel fastened into the impulse roller, moves the roller and causes the balance wheel to oscillate.

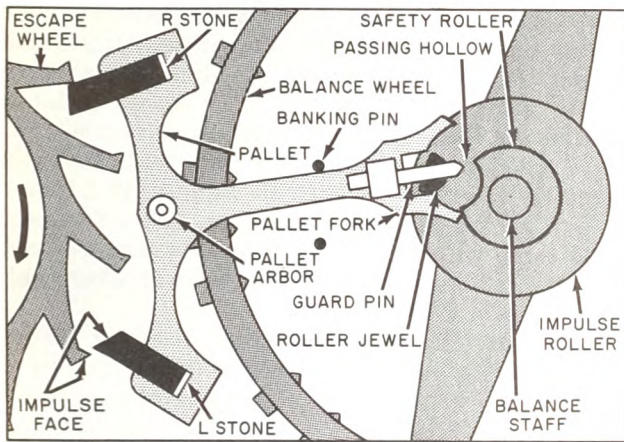
As the hairspring swings back and forth and makes the balance wheel oscillate, it carries the roller jewel back and forth across a centerline. Study figure 12-6. Parts shown are half in the

upside-down position and half right-side up for clarity. (The line between a and b is the centerline through the escape wheel, pallet, and balance



61.70X

Figure 12-4.—Some jewel positions in the transmitting mechanism.



61.71X

Figure 12-5.—Escapement unit in the controlling mechanism (half in upside-down position for clarity).

wheel.) When the roller jewel approaches the centerline and enters the position shown in part A of figure 12-6, it strikes the inside wall of the fork slot. As the roller jewel approaches the centerline, it moves the fork as indicated in part B of figure 12-6 and causes the right pallet stone to unlock an escape wheel tooth. The right pallet stone (R) is the receiving pallet; the left pallet stone (L) is the let-off or discharging pallet.

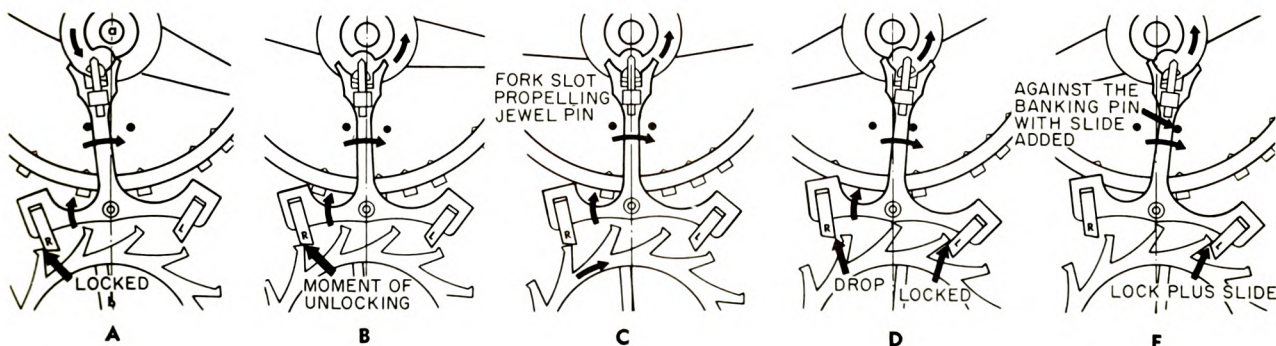
When an escape wheel tooth unlocks, it releases the escape wheel and creates an impulse on the right pallet stone. The impulse begins at the instant of unlocking. This impulse

pushes the pallet stone out of the path of the tooth. At this point, the fork pushes against the roller jewel and supplies the energy required to keep the balance wheel in motion.

After the escape wheel tooth slides off the pallet stone, it travels a short distance until another tooth locks onto the opposite pallet stone (part D of figure 12-6). Actually, the pallet moves slightly farther than the locking point because of the draw, which tends to hold it against the banking pin. (Draw is the result of the force exerted by the escape wheel tooth on the locking face of the pallet stone.) The small additional distance moved by the stone on the tooth is called the slide (part E of the figure 12-6). The balance wheel turns until the energy stored in it from the impulse is overcome by the tension in the hairspring, pivot friction, and air resistance. When the balance wheel and roller jewel are returned to the fork slot by the hairspring, the cycle of the escapement action starts over.

INDICATING MECHANISM

You know how the face of a watch looks. It has a second hand, a minute hand, and an hour hand. The dial is graduated into hours and minutes. The cannon pinion is frictioned to the lower end of the center wheel arbor, which extends up through the dial and carries the minute hand. It turns once per hour. (Recheck fig. 12-4.) The cannon pinion turns an intermediate gear, and the pinion of that gear turns the hour wheel which is telescoped over the cannon pinion and carries the hour hand. The second hand is usually mounted on the fourth



61.72X

Figure 12-6.—Underneath view (half from top for clarity of the escapement cycle).

wheel arbor, which projects up through the dial if a second hand is to be installed.

The winding and setting mechanism of a watch is illustrated in figure 12-7. It consists of a crown and stem connected to a system of gears that revolve an arbor and wind the mainspring. By pulling the crown and stem outward, you shift a setting lever (detent), clutch lever and clutch, and engage the clutch with the setting wheel. Since the setting wheel is enmeshed constantly with the minute wheel, you can now set the hands of the watch to the desired position. When finished with the setting, push the crown back in.

WATCH REPAIR TOOLS

Your ship's instrument shop will have the best tools and equipment available. Your primary concern, therefore, will be learning how to use and care for watch repair tools. The following sections describe the tools and give the general procedure for using them. As you advance in rating and get experience in the shop, you will gradually become proficient in their use.

WATCH REPAIRMAN'S BENCH

A properly constructed workbench is most essential in watch repair. A typical bench is illustrated in figure 12-8. Note the large number of drawers of various sizes in the desk. These

are necessary for the proper protection of all types of tools and watch parts. There is a small tray, called an apron, beneath the four drawers in the top center and left side for catching small items or parts which the repairman may drop while working on a watch. (The apron must be pulled out far enough to catch dropped items.)

A good light is absolutely necessary in watch repair. The one shown in figure 12-8 has a goose-neck for easy adjustment, and a fluorescent lamp with reflector. Some repairmen use a frosted bulb of the desired power in an adjustable lamp with a metal shade.

The chair used should have a comfortable, padded seat, and a back that is adjustable up to 16 inches. It should also have castors.

EYE LOUPES

An eye loupe is an instrument with a magnifying lens which a jeweler uses to see better the fine screws and similar items in a watch. A loupe is round and generally of a size to stay in place in front of an eye when properly placed; some are made with an attachment for fitting over the frame of glasses (See fig. 12-9.)

Two types of eye loupes are used most for watch repair work: (1) the 3-power size for general use, and (2) the 10-power size for examining pivots and jewels, adjusting balance springs, and similar fine work.

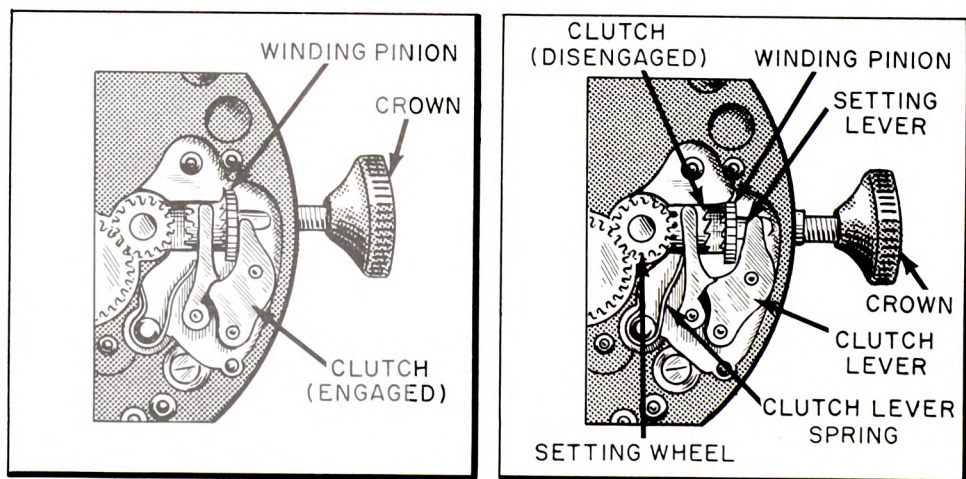


Figure 12-7.—Winding and setting mechanism of a watch.

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Figure 12-8.—Jeweler's workbench.

SCREWDRIVERS

A standard watchmaker's screwdriver is about 3 inches long (fig. 12-9). The blade is made from small diameter wire or rod, of the size desired. The end of the blade should be shaped with enough taper to prevent it from slipping out of screw slots and marring screw-heads or watch parts. A larger screwdriver, with a blade about 2.5 mm, is good for inserting and removing screws where considerable pressure must be applied.

Always select the type of screwdriver best suited for a particular job. It is best to use one with a blade so ground that it creates a slight wedging action when you press it into the screw slot, to hold the screw firm as you apply pressure while releasing or inserting it. The correct

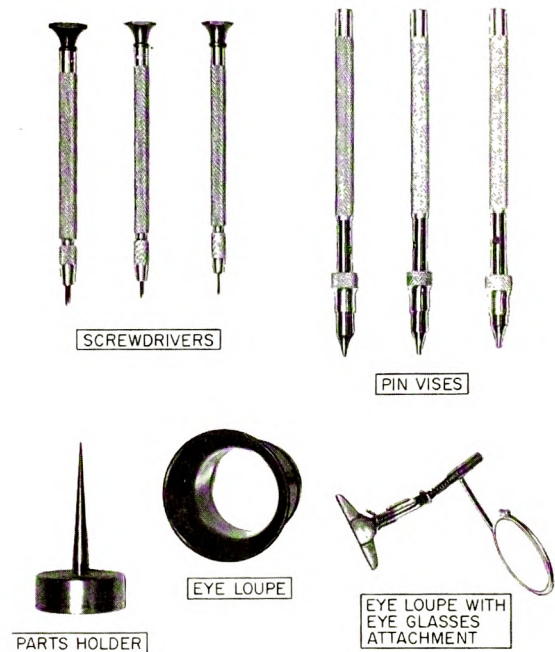


Figure 12-9.—Hand tools for watch repair.

procedure for holding a watch repair screwdriver is illustrated in figure 12-10. By holding it this way you can apply pressure with the index finger and turn it in either direction with the thumb and middle finger.

Maintain screwdriver blades in perfect condition. Grind bent or broken ends back to the original shapes on a Carborundum grinding wheel, or with a hard handstone. Keep the ends of blades square, so that they fit perfectly in screw slots. When not in use, stow screwdrivers in a safe place.

TWEEZERS

A watch repairman needs tweezers of different sizes and shapes. Some types are shown in figure 12-11. The small tweezers shown at the bottom of the figure are popular with most watch repairmen because they can be used for so many different purposes. Overcoil tweezers are good for putting an overcoil in



Figure 12-10.—Correct way to hold a screwdriver.

Brass tweezers are used for holding watch pivots and must therefore be made. Tweezers with curved and pointed ends are excellent for getting to and working on certain parts of a watch.

Five different types of pliers are essential in watch repair. Five different pairs of pliers are illustrated in figure 12-12. For general use, long-nose pliers illustrated are preferred. For delicate work, the narrow, tapered-nose pliers are best. For manipulating wire and springs, round-nose pliers are most suitable. For holding finished surfaces, always use brass-lined pliers to protect the

cutting pliers with thin edges are used for tightening cannon pinions. Most pliers have an adjustable stop screw in one handle, behind the head, to prevent cutting the work when a considerable amount of force is applied on the handles.

Pliers used in watch repair are delicate and require careful protection. Keep them free of grease, oil, or any foreign substance. When necessary, use a file or approximator to file or grind them into proper working condition. Pliers with fine teeth require extra protection. It is best to use a special holder for pliers, with a special

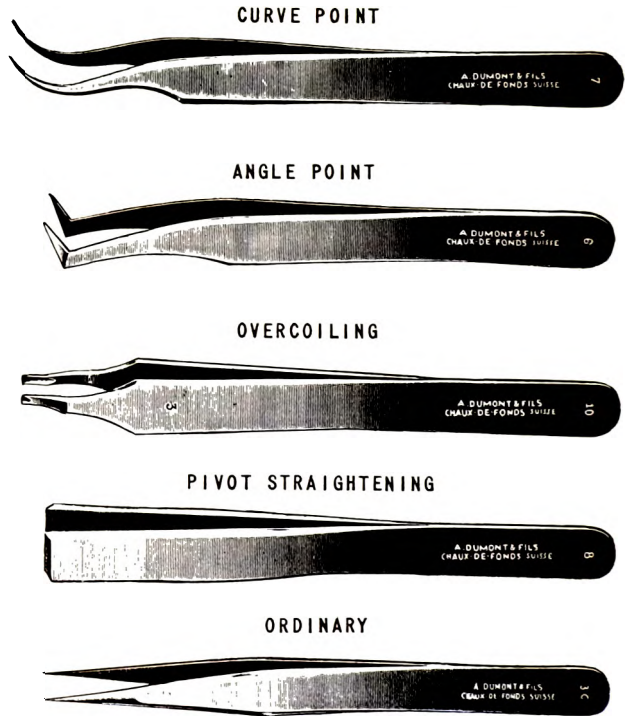


Figure 12-11.—Tweezers used in watch repair.

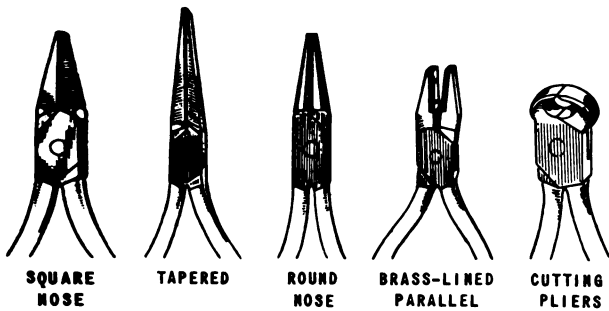
compartments for each pair. If you put them with other tools, damage will very likely result.

CALIPERS

You need calipers to get the correct diameters and thickness of metal parts used in watches. Metric micrometer and vernier micrometer calipers are the ones generally used for this purpose. A micrometer with a vernier scale is essential for getting exceptionally accurate measurements. One of your responsibilities as an IM2 will be to clean, oil, and adjust micrometers. The procedure for reading, cleaning, and adjusting micrometers is discussed in detail in Basic Handtools, NavPers 10085-A. Refer to this text when you need information about micrometers.

JEWELER'S LATHE

For sharpening tools, polishing and burnishing, making watch parts, and doing other work, a jeweler's lathe is an indispensable machine. As an IM3 or an IM2, you may have the responsi-



1.21(61)D

Figure 12-12.—Types of pliers required for watch repair.

bility for care of the lathe and chucks used with it. You must also know what chuck number to use with a given diameter of stock used for making a screwdriver or watch part. With training and experience, you will be able to sharpen gravers and screwdrivers and polish parts. When using the lathe you should be careful to avoid injury to fingers; also wear goggles to protect the eyes when grinding.

A popular type of jeweler's lathe is illustrated in figure 12-13. It is made of steel and has a single pedestal for a base, to allow for free hand movement while you are working. Note that it has pulleys of different sizes for the belt from the motor to run in. The smaller the pulley used on the lathe, the faster the motor drives the part held in the lathe with a chuck. The parts of a lathe are: (1) bed, (2) headstock, (3) tailstock, and (4) T-rest. There is a slot in the middle of the bed, to allow for back-and-forth movement of the T-rest, which is used to rest gravers and other tools on while you are turning or grinding a part. In figure 12-13, small chucks are in place in a holder on the back of the lathe; a large chuck is on the right. The foot switch for the motor is shown on the lathe in the illustration; but when the lathe is in operation the foot switch is placed on the floor. It has a built-in rheostat which controls the speed of the motor in accordance with the amount of pressure applied to the switch.

Protect the lathe and accessories with a cover when not in use. Clean chucks and gravers with a cloth moistened with a recommended cleaning solution and wipe them dry with another cloth. Remove dirt, oil, grease, and other foreign matter from the lathe. Disassemble, clean, and reassemble as frequently as recom-

mended by the instruction manual provided by the manufacturer. Wipe dust from the motor and refill oil and/or grease cups as recommended. After reassembly, adjust the headstock as necessary to eliminate play or end-shake.

GRAVERS AND CHUCKS

Hand gravers are tools you use while turning a part on the lathe. They are made from hardened steel, and the heads are ground in the shape of diamonds or rectangles. The points vary in accordance with requirements. (See fig. 12-14.) The all-around graver is used for roughing out most work, while an undercutting graver is excellent for undercutting or finishing a corner. For heavy cutting, use a graver with a round nose. A squarenose graver should be used for turning a bevel.

When using a hand graver, rest it on a T-rest (fig. 12-13) for cutting control. Exert sufficient pressure to do the cutting required, but not so much that you break the point. The heads are delicate and break easily. Skill in the use of gravers comes with practice.

Sharpen gravers with a hard hand oilstone or on a stone held in a chuck in the lathe. Use a few drops of oil on the stone. When finished with the sharpening, remove burrs or feather edges from the cutting blades, to prevent scratching watch parts when you use the graver.

A chuck is a tool used for holding a part in the lathe. The diameter of the chuck used must be the same as that of the piece; otherwise, the chuck will not hold the piece true in the lathe. It is therefore advisable to have a large assortment of different sized chucks, as illustrated in figure 12-13. Large chucks with adjustable jaws are used for holding parts with varying diameters, or for holding them in different positions.

NEEDLE GAGE

When a jeweler needs to determine the size of a jewel hole, he can do so with a needle gage (fig. 12-15). To measure the size of a jewel hole, put the jewel on the needle, as illustrated. Hold the jewel with the thumb and index finger and push in toward the body of the gage. When you push on the jewel, it slides up the needle until it fits perfectly. Continue pushing on the jewel until it rests tightly against the body of the gage.

A pointer (index) is secured to the base of the needle. When you push on the jewel on the

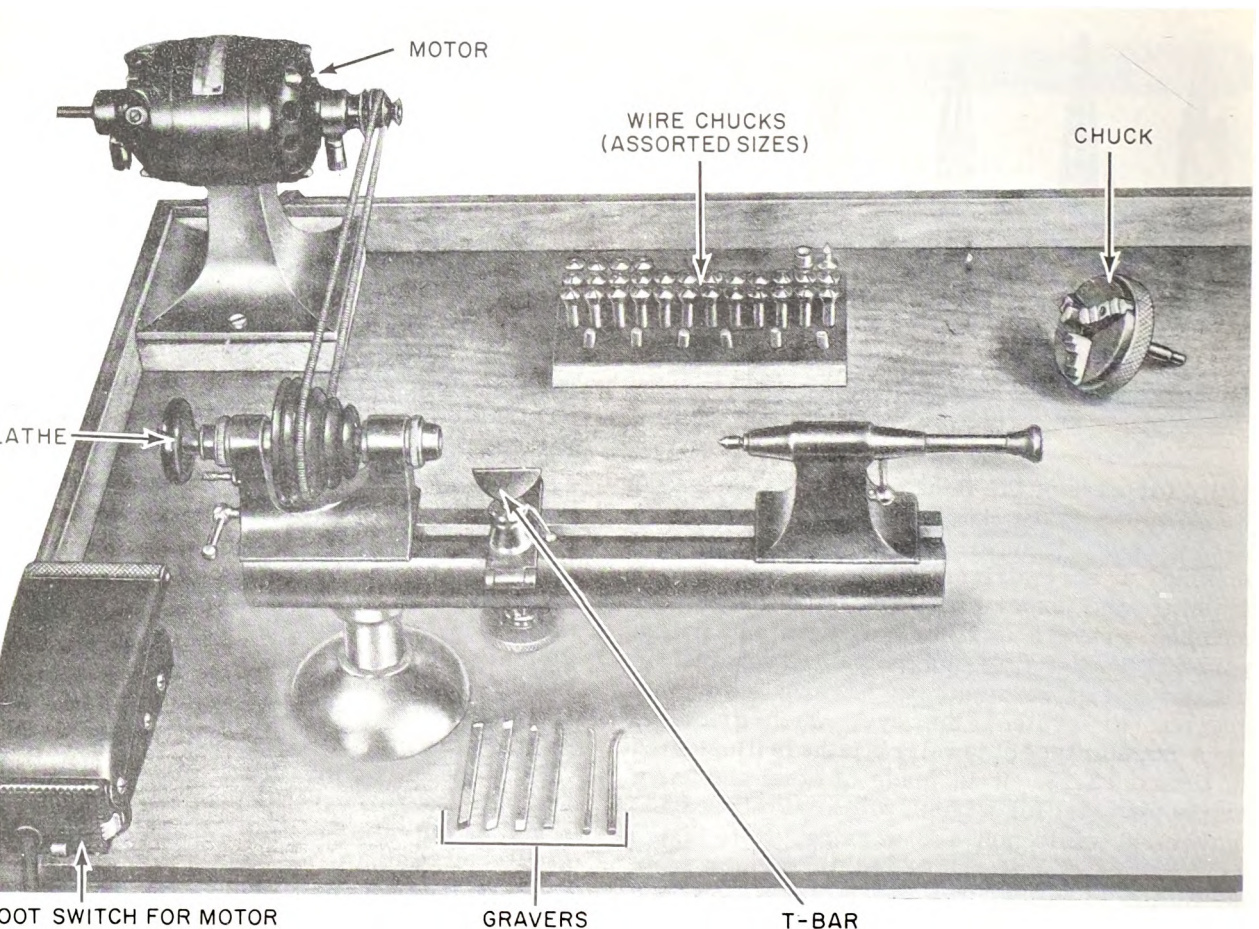


Figure 12-13.—Jeweler's lathe and accessories.

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iddle and slide the needle back, this pointer indicates on a scale on the gage body the correct diameter of the hole in the jewel.

JEWELLED PIVOT GAGE

A jeweled pivot gage is used to get the correct size pivot to operate in a jewel of a particular size. Each hole in the gage has a jewel in it, and the holes in the gage are graduated in size. Figure 12-16 illustrates three different sized jeweled pivot gages. The holes of the small gage increase in size by 0.0025-millimeter increments. The medium sized gage has holes graduated by 0.005-millimeter increments, and the largest gage has holes graduated by 0.01-millimeter increments.

STAKING TOOL

It would be rather difficult to fix a balance wheel rigidly to a balance staff without a staking tool. Study the staking tool and accessories in figure 12-17; a staking tool with different sized holes in its base, some punches (seating, spreading, and riveting), and a set of stumps are shown.

To stake a balance wheel to a balance staff, find the correct-size hole in the anvil, or use an inverted punch, and then center the hole or punch. Insert the balance staff into the centered hole or punch. (Study this procedure in fig. 12-18.) Next, put the balance wheel on the balance staff and push it down as far as possible. With a seating punch and light hammer, force the

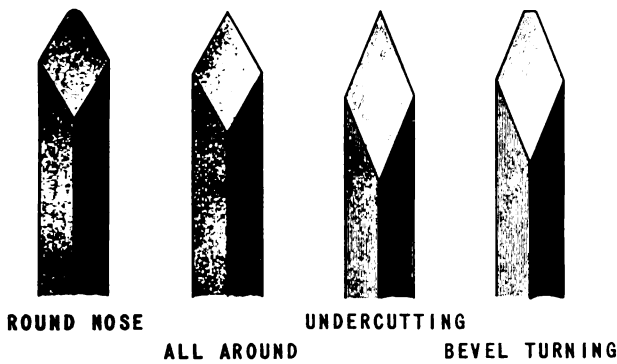


Figure 12-14.—Hand gravers used in watch repair.

balance arm of the balance wheel down onto the balance staff. Then use a spreading punch (with smaller opening in end) to spread the riveting shoulder. Strike the punch lightly with a brass hammer. Finally, use a riveting punch (flat end) to flatten out the riveting shoulder, as illustrated. This completes the staking process—fitting the balance wheel to the balance staff.

BALANCE TRUING CALIPER

Balance truing means the bending of the rim of a balance wheel of a watch in such a manner that (1) all parts of the rim lie in the same plane, and (2) the entire rim is perpendicular to the staff axis. The instrument required for doing this job is known as a balance truing caliper (fig. 12-19).

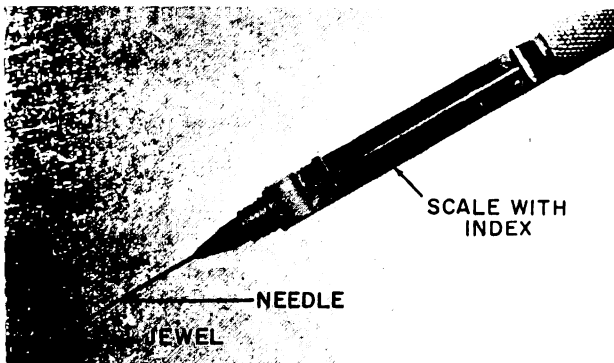


Figure 12-15.—Needle gage used for measuring sizes of jewel holes.

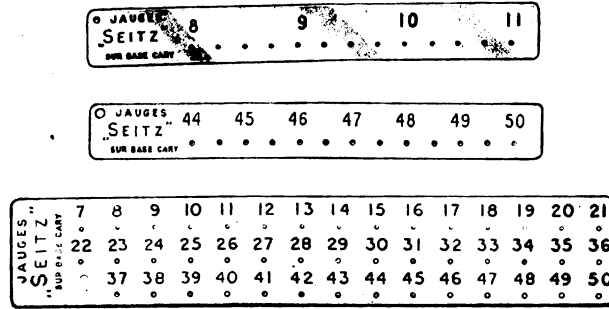


Figure 12-16.—Jeweled pivot-gages.

Figure 12-20 shows a balance wheel in a balance truing caliper in the correct position for truing in the flat (same plane). Note the position of the index (pointer). It is just above the rim of the wheel. Now, when you turn the balance wheel the space between the two arms and the pointer should be equal. If this is true, the balance wheel is true in the flat. If it is not true in the flat, use your thumb and fingers to bend the rim above the arm which shows too much space between the arm and the pointer. Then spin the wheel and check the space again. Continue in this manner until the wheel is true in the flat.

To true a balance wheel in the round, readjust the index so that it is just above the outside surface of the rim. Then spin the wheel slowly and observe the space between the outside surface of the rim and the index. If it is the same all around, the wheel is true in the round. If the wheel is not true in the round, use a rim wrench (fig. 12-19) to bend the rim wherever necessary to get it true. Turn the wheel and bend when you detect an untrue area. Continue this procedure until the wheel is true in the round.

POISING TOOL

A poising tool is used to check the weight of screws in the rim of the balance wheel at any point on the rim. Unless the weight is the same all around, the watch will not keep good time. Refer to figure 12-19, which shows a poising tool. The knob at the big end of the tool is for adjusting the vise to the length of the balance staff for different sized balance wheels.

If you place a balance wheel (without hair-spring) in the poising tool and put it in motion with your finger, it should turn slowly all

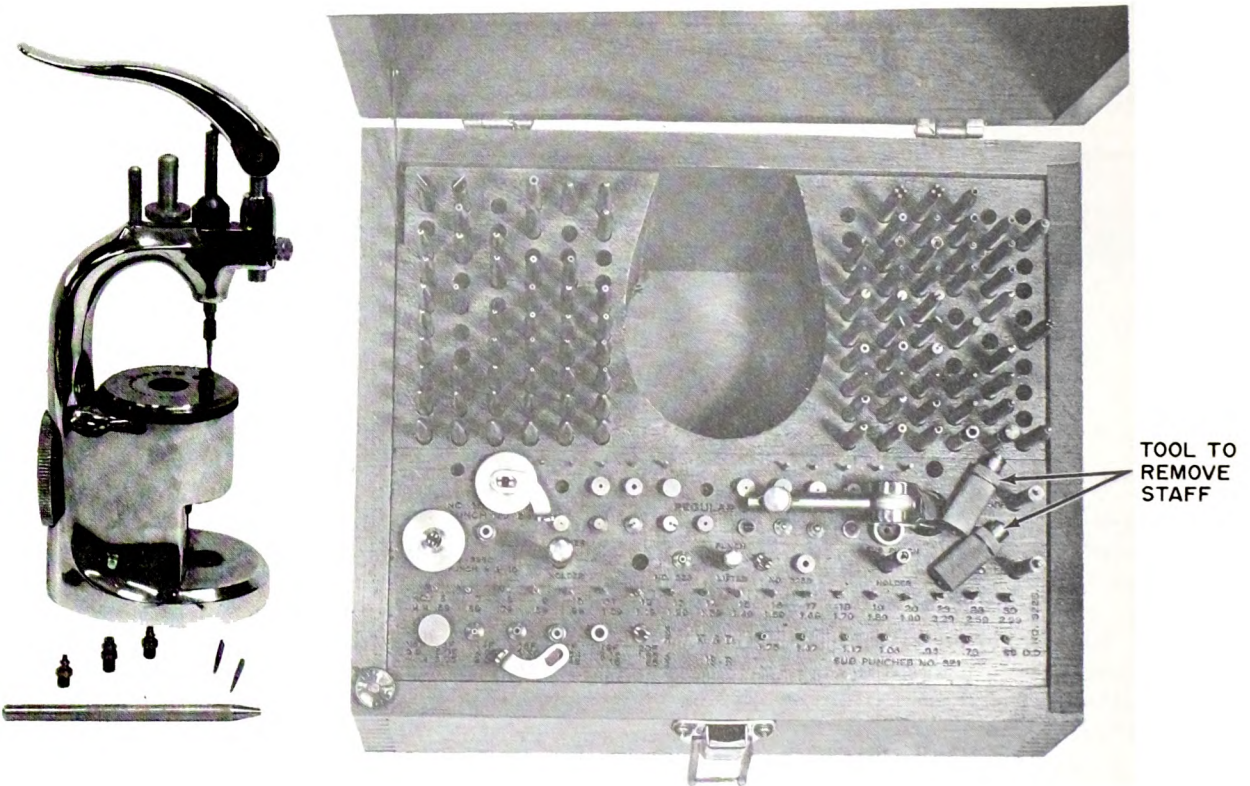


Figure 12-17.—Staking tool and accessories.

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ound. If the wheel is not in poise, gravity
 ls the heaviest portion of the rim down to the
 vest point and the wheel stops. If this happens,
 move the brass screw at this point and use the
 balance screw undercutter to remove a small
 amount of metal from the underside of the
 rewhhead. Then put the screw back into place
 and turn the wheel again. Continue in this man-
 ner until the wheel is in poise.

Balance wheels have meantime screws.
 These are used for regulating the time of the
 watch. When poising a wheel, therefore, do not
 touch these screws. If there is too much weight
 on the position of a meantime screw, take a
 small amount of metal from the screw on each
 side of the meantime screw.

JEWELING TOOL

A friction jeweliling tool makes the job of
 setting jewels into position in a watch com-
 paratively simple and easy. One is illustrated

in figure 12-21. It consists of a set of reamers,
 a set of pushers, and an assortment of stumps.
 (NOTE: The hollow stump acts as an anvil.)

To use a jeweliling tool, proceed as follows:
 (See fig. 12-22).

1. Use a reamer (self-centering reamer) of the correct size and ream out the jewel hole; it should be slightly smaller in diameter than the jewel.
2. Select a correct size jewel and place it at the top of the jewel hole.
3. If the jewel is to fit even with the top of the part into which you are placing it, use a pusher larger than the jewel hole.
4. If the jewel is supposed to fit slightly below the surface of the part into which it is being inserted, use a pusher slightly smaller than the jewel hole.

It will be evident, even from this brief description, that friction jeweliling is a most important advance in watchmaking. Because of

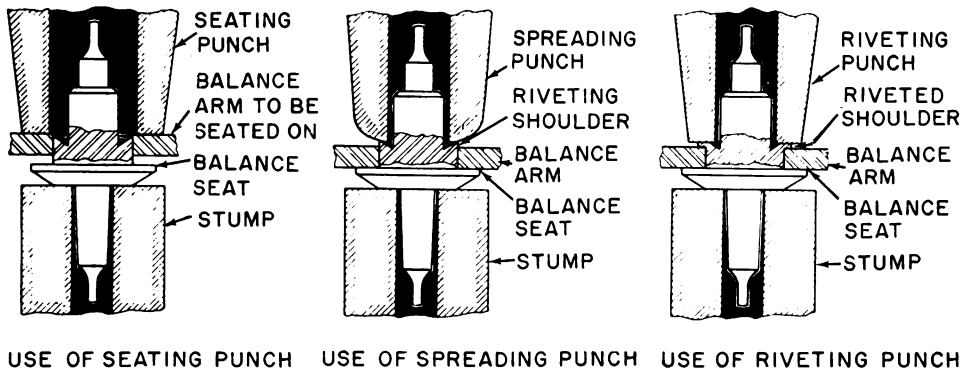


Figure 12-18.—Procedure for staking rivet-type balance staff.

friction jewelers, watches today are simpler, less costly to make, more accurate in performance, and very much easier to repair.

Through experience, you will become proficient in the use of a jewelers tool. You will have much use for this tool and must be able to use it skillfully.

DEMAGNETIZING MACHINE

Since watches and clocks have steel in their mainsprings, winding mechanisms, and pinions, they are always susceptible to magnetism. When a piece of iron or steel is placed in a magnetic field, the molecules shift around in such manner that all the south ends point one way and all the north ends point the other way. The piece of steel then becomes magnetized. When a watch is in a magnetic field, its steel parts may become magnetized.

Magnetism does not seriously affect the operation of a mainspring; but a magnetized hairspring, roller, or fork does affect the accuracy of a watch. The coils of a magnetized hairspring, for example, stick together or touch the balance arm occasionally and cause irregular timing. If strongly magnetized, a hairspring will be attracted to the balance arm and cause the watch to stop.

Alternating current does not greatly affect watches and clocks because their magnetic fields are constantly changing in direction and intensity. Direct current, on the other hand, has a decided effect on the iron and steel parts of a timepiece, because its magnetic effect lines up the molecules permanently. Aboard ship, a watch always becomes magnetized when it is

near the ship's degaussing gear, or if it goes through a deperming operation. (Deperming is a reduction of permanent magnetism by energizing coils placed vertically around the ship.)

The first thing you should do with a watch or clock brought to the instrument shop for repair

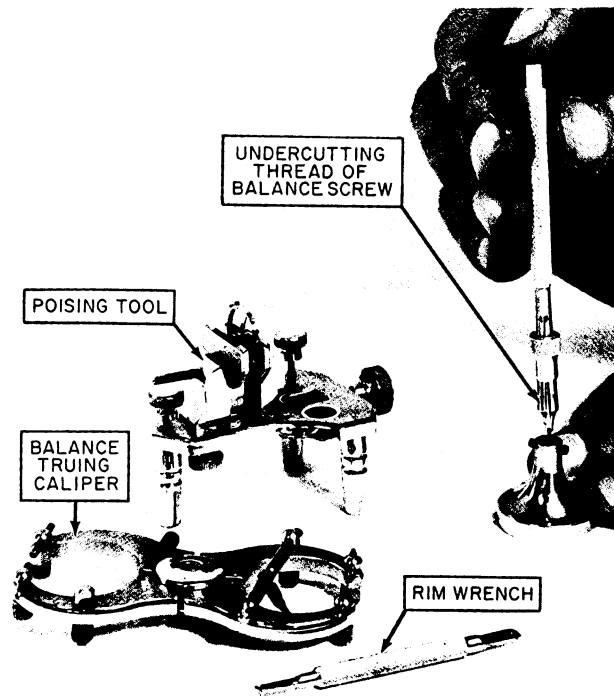
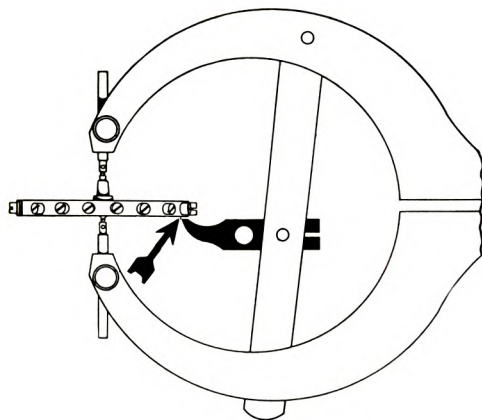


Figure 12-19.—Poising tool, balance truing caliper, and rim wrench.



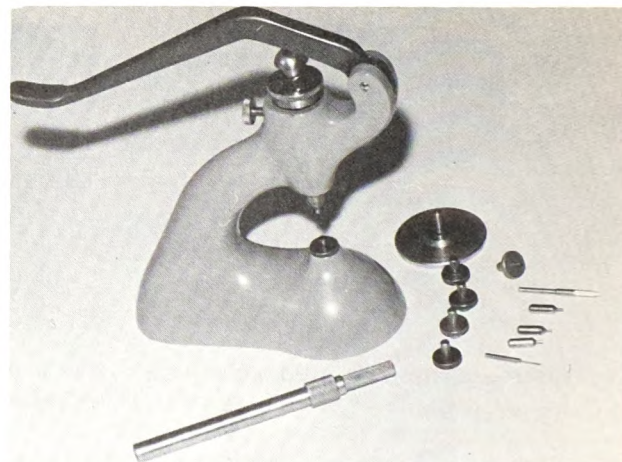
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Figure 12-20.—Balance wheel in caliper for truing in the flat.

is to see that it has been tested by the RADCON (radiological control) division which checks the mechanism, particularly if it has a luminous dial, for radioactivity. Then check it for magnetism by removing the back and placing a small compass on the top of the balance cock, directly over the upper balance endstone. If the watch is magnetized, the compass needle vibrates back and forth. The needle may sometimes make a complete revolution and spin around its axis rapidly. This indicates a magnetized hairspring.

If the needle of the compass remains stationary, always pointing north, the watch is not magnetized. If the needle shivers and seems to stick at times, the hairspring is not magnetized, but the mainspring or winding mechanism probably is.

You can demagnetize a watch with a demagnetizing machine (fig. 12-23). This machine operates only on 115-volt, 60-cycle, alternating current. Plug the cord into a socket and turn the switch on. Hold the watch in the coil of the machine for 3 or 4 seconds. Then slowly draw it out and away from the machine. When it is at arm's length, switch the current off. The demagnetizing machine produces inside and around the coil a powerful alternating magnetic flux which acts on the molecules of the magnetized parts and causes them to return to their original condition as they leave the machine. Test the watch with a compass. If some magnetism still remains, repeat the process.



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Figure 12-21.—Jeweling tool and accessories.

MAJOR COMPONENTS OF CLOCKS

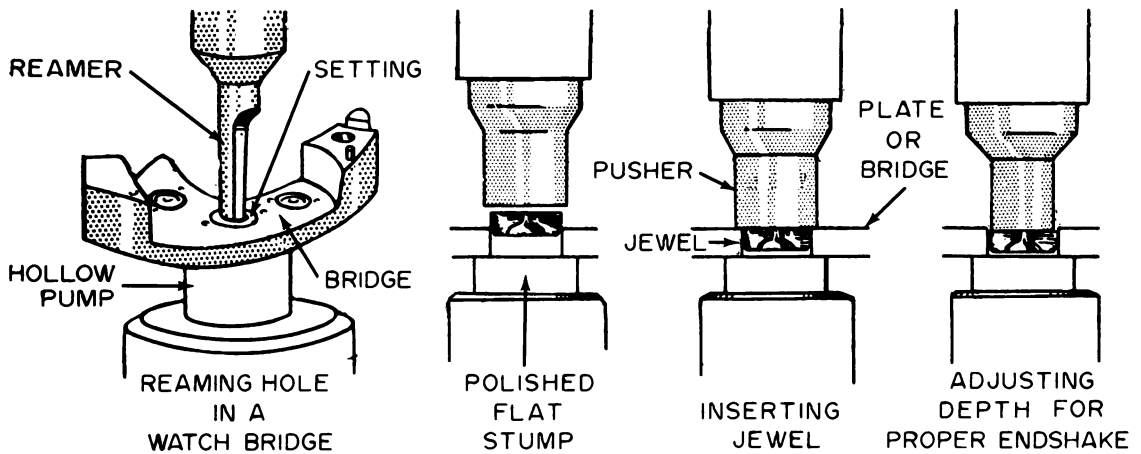
In this section we discuss the mechanisms of clocks used on Navy ships and stations and the tools used in clock repair.

Chelsea and Seth Thomas boat, deck, and mechanical clocks are constructed in accordance with Navy specifications, to fulfill all the Navy's requirements for timepieces of this type. Basically, they consist of an eight-day movement enclosed in a metal or black phenolic case, which is dust- and moisture-proof and has a cushioned bulkhead mounting plate. These clocks (mechanical excluded) have a lusterless black 12-hour dial and luminous hands and dots next to the numerals, and some are equipped with sweep second hands.

Boat and deck clocks are wound, set, and regulated through a dust-proof cover in the back of the case; and they have 3 1/2 or 6-inch dials and weigh 4 1/4 or 7 pounds, respectively. Mechanical clocks are wound and regulated through the dial, and are used for general purposes, where boat and deck clocks are not required. They have 6 or 8 1/2-inch dials and weigh 3 or 5 pounds, respectively. The clock mechanisms and parts are discussed in the paragraphs which follow.

PLATES AND BRIDGES

The foundation of clock movements is the front plate, illustrated in figure 12-24. Other spring is contained in a barrel. Observe the



61.87X

Figure 12-22.—Inserting a jewel with jeweling tool.

plates and bridges which support moving parts are fastened to the front plate by pillars. Note the height of the back plate pillars, as compared to the height of the train plate pillars and the fourth upper bridge pillars. There are three major groups of parts which work together to drive the clock hands and to keep the correct time—the power assembly, the train, and the escapement.

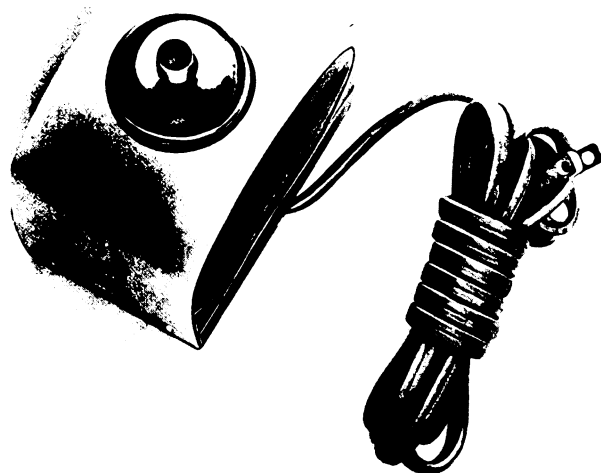
As shown in figure 12-24, some clock movements have three plates and one bridge; but some movements do not have a fourth upper bridge. Those with eccentric second hands have the upper pivots for the intermediate, center, third, and fourth wheels included in the train plate, which also has provisions for mounting the escapement. The train plate contains pivot holes for the intermediate and center wheels, and the back plate contains the upper pivot hole for the mainspring barrel.

Movements with sweep second hands have the upper pivot holes of the third and fourth wheels in the fourth upper bridge. The starting knob and setting shaft of some clocks are mounted on the back plate, as are four pillars to which the dust cover is secured.

Now study figure 12-25, and compare it with the clock movement illustrated in figure 12-24. Note in these illustrations that the perpendicular broken lines indicate where screws and parts fit in the whole mechanism.

POWER ASSEMBLY

The power assembly contains the main spring and all the parts necessary to wind it and to allow it to run down in the proper direction. The power assemblies of two different types of clocks are shown in figure 12-26. Like conventional watch and clock movements, the mainspring is contained in a barrel. Observe the



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Figure 12-23.—Demagnetizing machine.

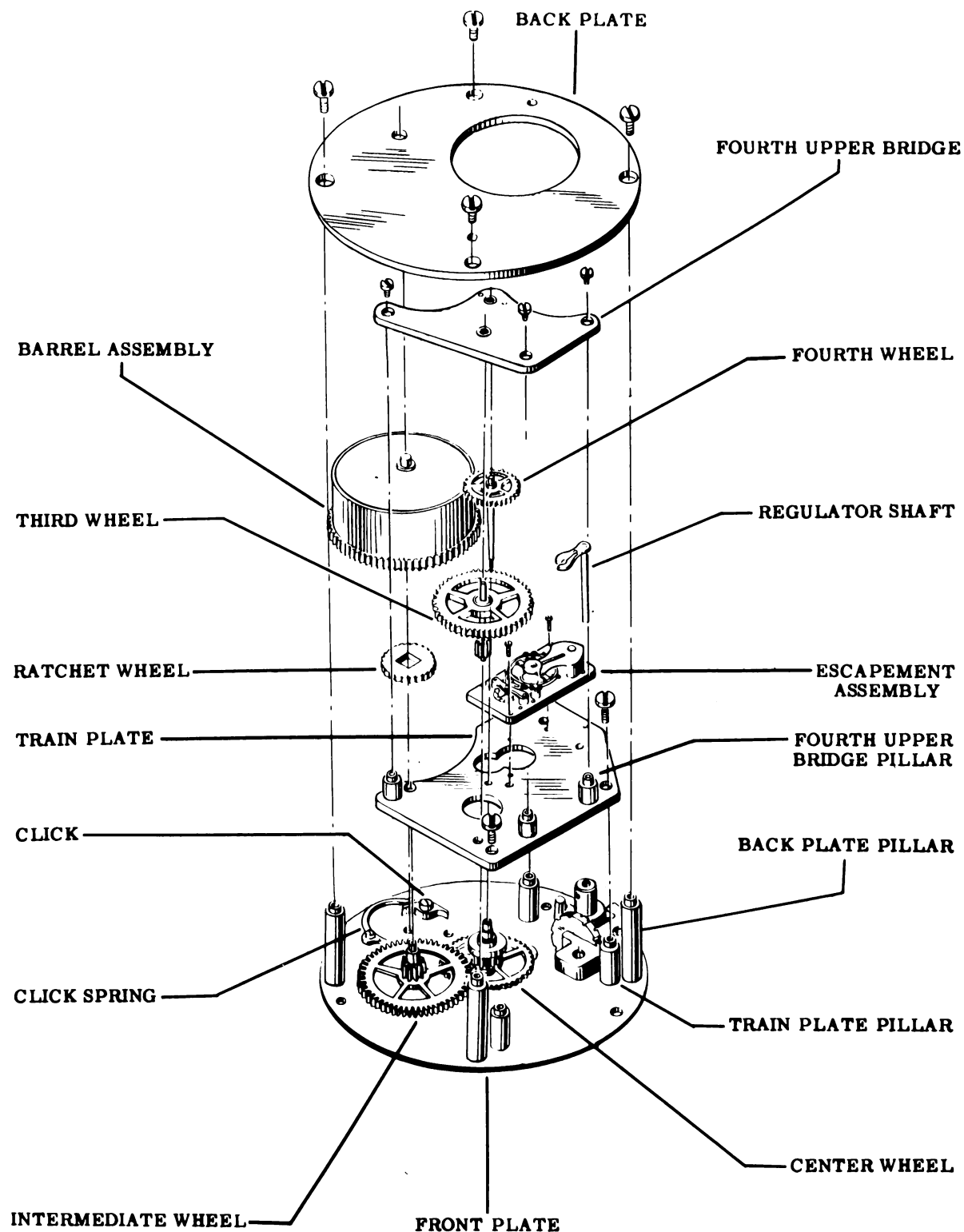


Figure 12-24.—Chelsea mechanical clock movement.

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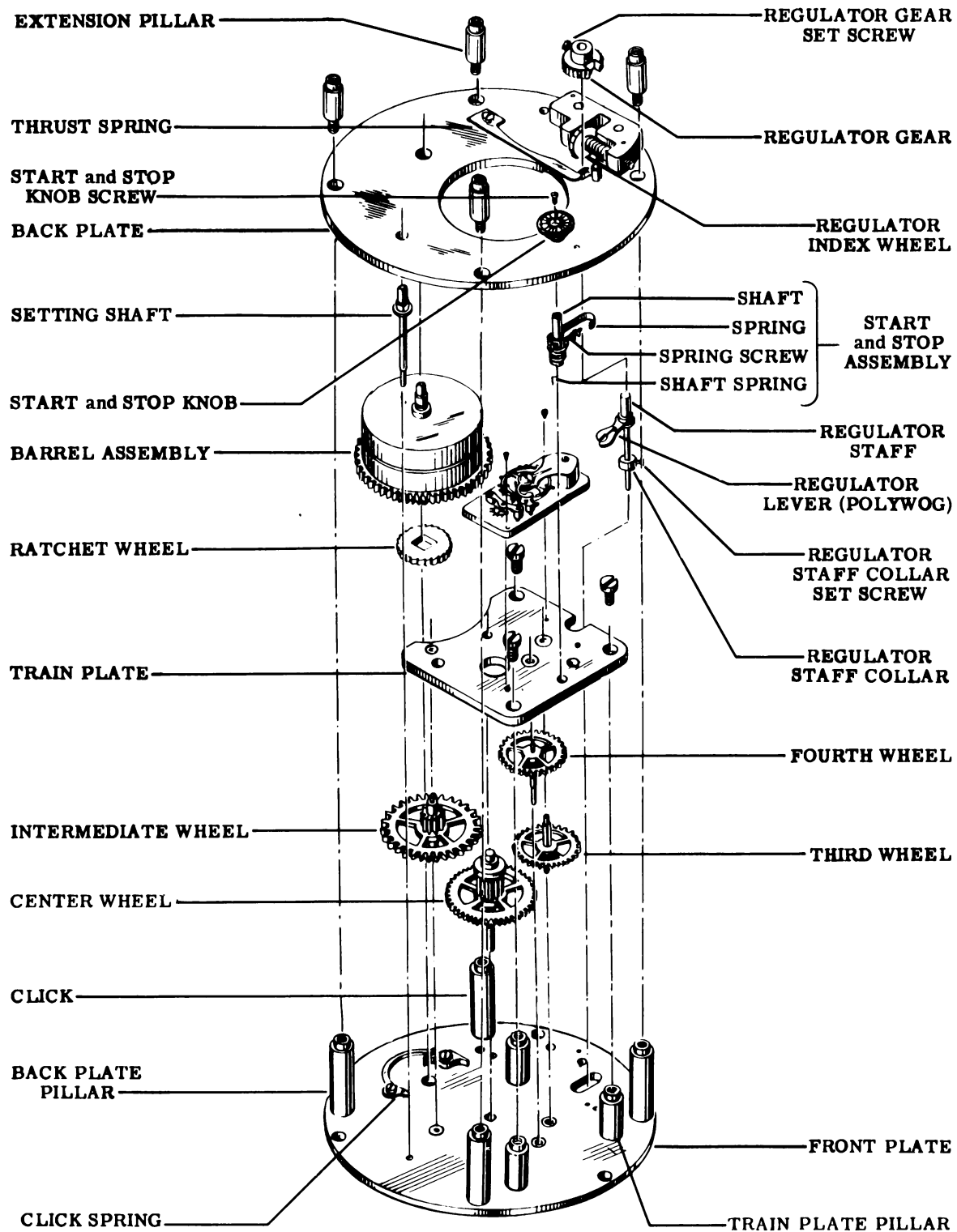


Figure 12-25.—Chelsea boat and deck clock movement.

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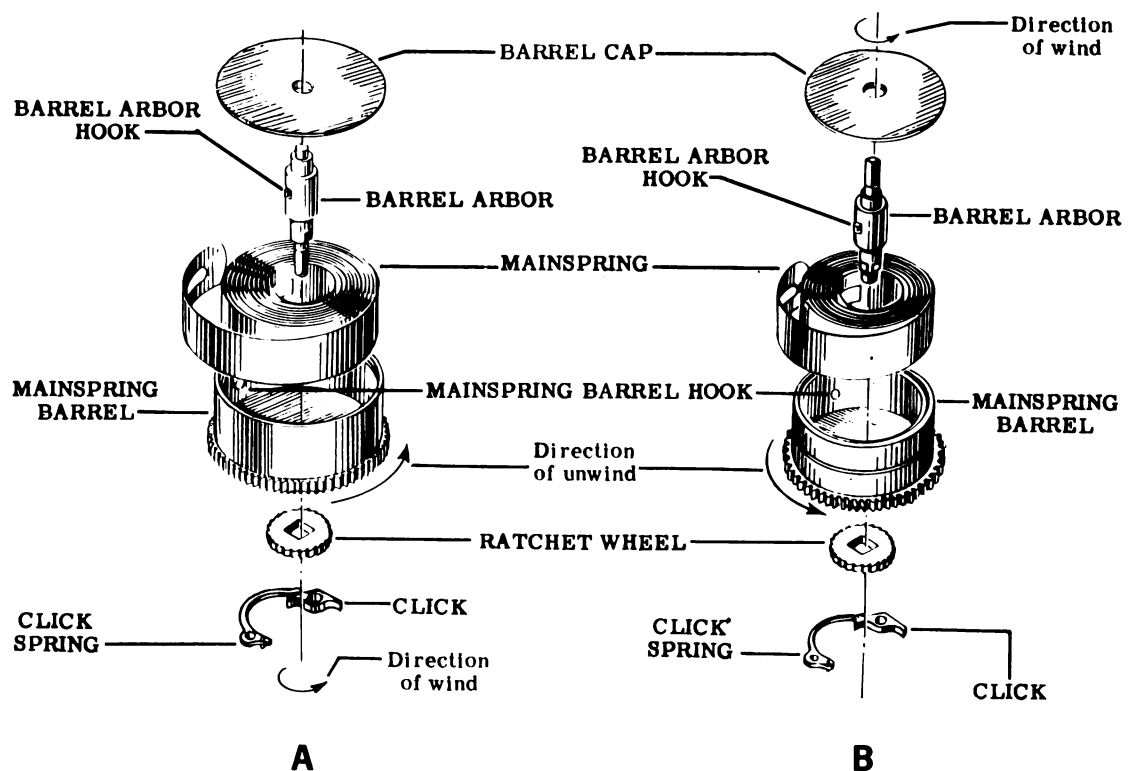


Figure 12-26.—Clock power assemblies.

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hook on the barrel arbor to which the inner end of the spring is attached, and also the hook on the inside of the barrel to which the outer end is secured. The barrel arbor in part A of figure 12-26 is so positioned that the mainspring can be wound through the dial attached to the front plate. In the movement shown in part B of figure 12-26, the ends of the barrel arbor are reversed.

The key for winding the mainspring fits on the squared end of the barrel arbor. As the spring is wound, a click (held in place by a spring) engages and locks the teeth of a ratchet wheel mounted on the barrel arbor just behind the front plate. The click allows the barrel arbor to turn in a clockwise direction ONLY.

As you can see from the above explanation, the power assembly of these clocks is so designed that the mainspring can unwind ONLY by turning the barrel, which is geared to the main train of the clock.

THE MAIN TRAIN

Turn now to figure 12-27 and study the main train of one clock mechanism, and then compare it with the main train of another type of clock mechanism illustrated in figure 12-28.

The main train consists of the teeth on the mainspring barrel and the intermediate, center, third, and fourth wheels. Power from the mainspring is delivered to the escapement through the wheels in the order mentioned. Note that the teeth on the edge of the barrel constitute the first wheel in the train, as is also true of the watch main train, but the wheel driven by the barrel is called the INTERMEDIATE wheel. Some clock manufacturers call this wheel the SECOND wheel.

The center wheel has a long arbor which projects through the front plate and mounts a cannon pinion, as illustrated. Observe that the position of the wheels is different in the two

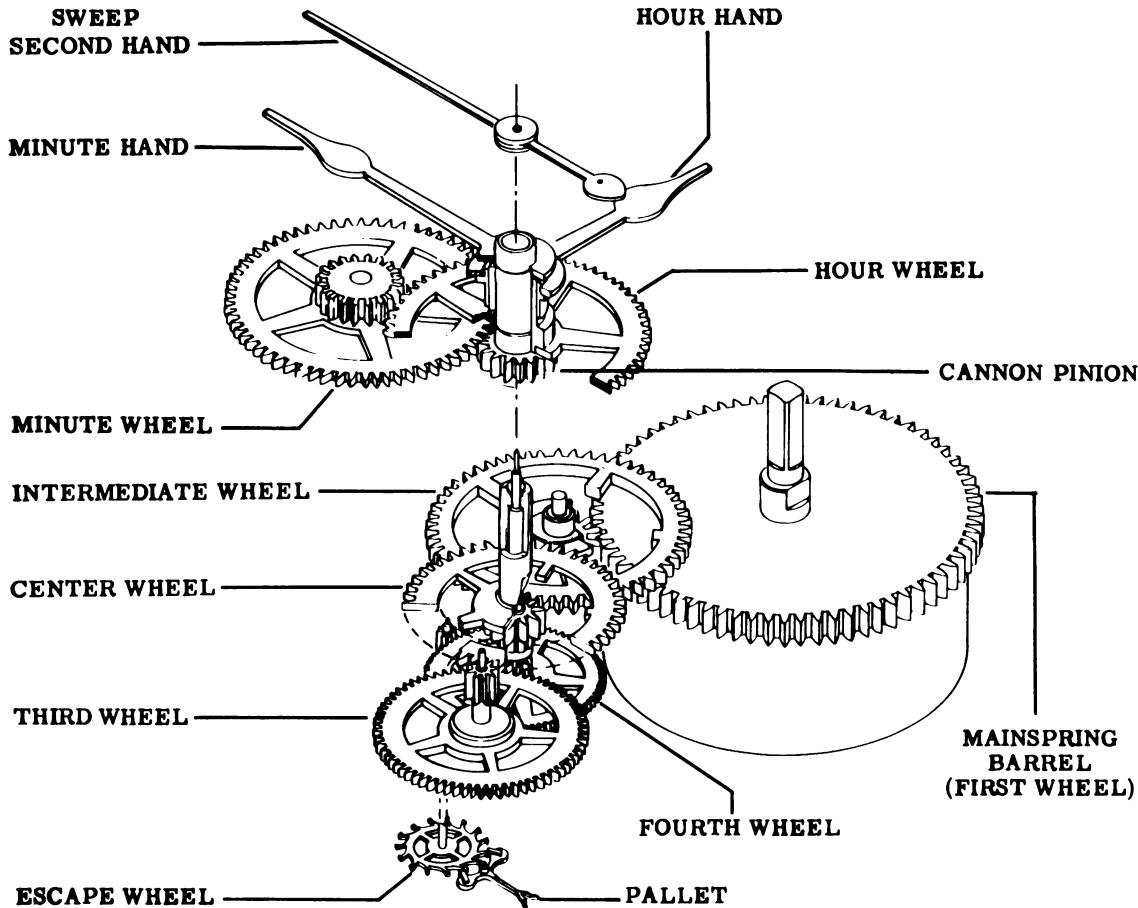


Figure 12-27.—Mechanical clock train.

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mechanisms. The reason for this is that the movement in figure 12-28 has an eccentric second hand which fits on the arbor of the fourth wheel. The setting pinion of this mechanism meshes with the minute wheel. The sweep second hand in the mechanism shown in figure 12-27 is also secured to the arbor of the fourth wheel, but note how it extends up through the arbor of the center wheel.

Study the pinions and arbors of the different wheels of the main train in illustration 12-27. Observe the hollow arbor of the cannon pinion, the center wheel assembly, and the long arbor on the fourth wheel. The minute hand is attached to the end of the cannon pinion, and the cannon pinion drives a minute wheel which drives an hour wheel, freely riding around the shaft of

the cannon pinion. As you learned previously, the cannon pinion, the minute wheel, and the hour wheel constitute the DIAL TRAIN.

THE ESCAPEMENT

A clock escapement, referred to as the "brain" of the clock, is shown in figure 12-29. The parts of this escapement are: (1) the escape wheel, to which power is transmitted from the mainspring through the fourth wheel of the main train; (2) pallet and escape bridges; (3) the pallet; (4) the balance wheel assembly; (5) the balance cock; and (6) an escapement plate, which forms the foundation for the entire escapement. It also contains the lower jewel

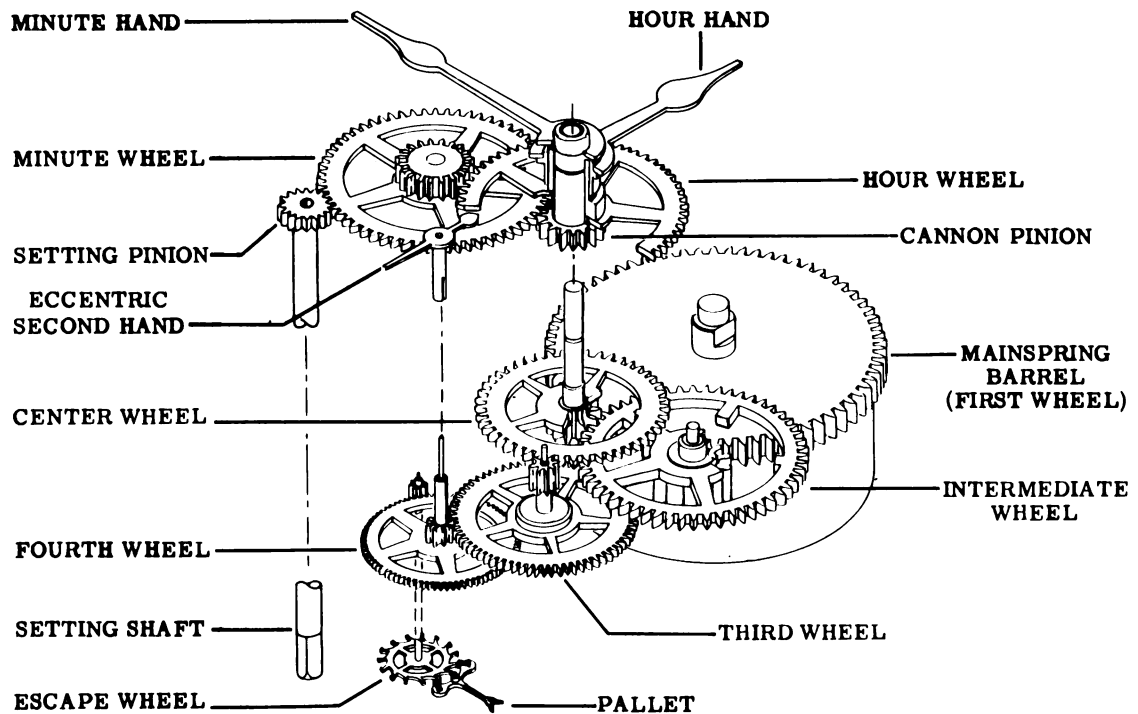


Figure 12-28.—Boat and deck clock train.

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bearings for the escape wheel, the pallet, and the balance wheel assembly. The balance cock contains the upper jewel bearings of the balance wheel assembly.

As mentioned earlier in this chapter, the escapement controls the unwinding of the mainspring in such a manner that the second, minute, and hour hands travel around the dial at proper speed. Each tooth of the escape wheel passes one of the locking jewels of the pallet at regulated intervals. As each escape tooth goes by, it delivers an impulse to a pallet jewel which transmits the impulse to the balance wheel. The back-and-forth motion of the balance wheel moves the pallet back and forth, thereby regulating the speed of release of the escape wheel teeth. The impulse from the pallet drives the balance wheel in one direction and then in another, the rotation being controlled by the hairspring. The roller jewel receives the impulse from the pallet fork to drive the balance

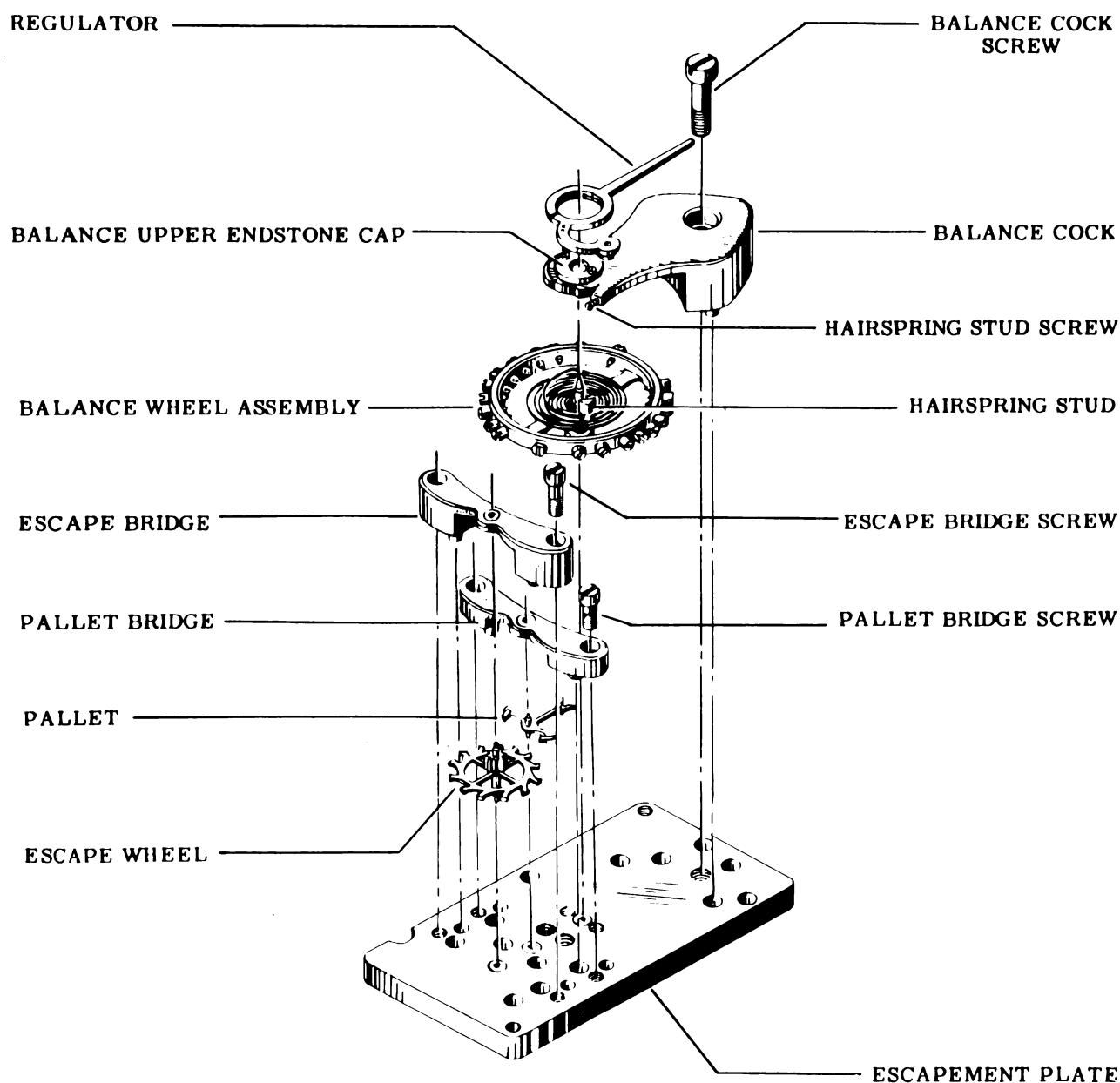
wheel, and the roller jewel also strikes the pallet fork to release each escape tooth.

CLOCK JEWELS

Navy mechanical, boat and deck clocks generally have eleven jewels: (1) one hole jewel and one cap jewel at each end of the balance staff, (2) one hole jewel at each end of the escape wheel and pallet staffs, (3) a balance roller jewel, and (4) two pallet jewels (stones). These jewels are at the point which receive the most wear; and they provide smooth operation, prolong the wear of parts, and give accurate time-keeping.

CLOCK REPAIR TOOLS

When you repair clocks, you need to know which tool to use for a specific purpose (job).



91.238

Figure 12-29.—Clock escapement.

For example, if you are going to work on a Chelsea escapement, you need an escapement block designed for that particular escapement, not one designed for a Seth Thomas or an Elgin escapement.

Information concerning maintenance and repair of clocks is covered in chapter 13 of this rate training manual. Detailed information can be obtained from technical manuals for specific equipment.

CHAPTER 13

WATCH AND CLOCK MAINTENANCE

As an Instrumentman 3 or 2, you will help to disassemble and clean watches and clocks. If there is a shortage of trained Instrumentmen, or if the workload demands it, you may be required to disassemble, clean, reassemble, and oil watches and clocks. This chapter gives the procedure for doing this work. By studying it carefully, and with some experience, you can acquire the skills necessary for doing a satisfactory job. Cleaning and oiling watches are tedious tasks and you must be very meticulous in your work. Many parts are very small and fragile; keep them segregated in wire baskets or containers to protect them.

This chapter provides a limited amount of information on the disassembly, cleaning, oiling, and reassembly of watches and clocks. Additional information is provided in Instrumentman 1 & C, NavPers 10194-B.

MAINTENANCE OF WATCHES

Watches, as well as clocks, used aboard ship and throughout the Navy must be reliable and accurate; and when maintained in excellent operating condition, they generally have these attributes.

In addition to learning how to disassemble and reassemble watch mechanisms, you are required to know what cleaning agents, lubricants, and preservatives to use for watches, as well as clocks.

DISASSEMBLY

The recommended procedure for disassembling a conventional watch follows. Illustrations show the various steps, which are considered next. If you break a screw during disassembly, use the recommended procedure for removing it. Illustrations and disassembly procedures outlined in this text are for a Hamilton com-

paring watch, model 2974. This watch is no longer made by the Hamilton company, but it is extensively used at this time aboard ship. The Hamilton Navigational Watch may in time replace the Hamilton comparing watch for use aboard ship; and the Hamilton Chronometer Watch, size 35, may also be used.

Remove Bezel and Hands

Hold the watch in one hand and unscrew the bezel with the other hand. Then put the watch on a movement block, face up, and remove the hands. See figure 13-1. Note arrow pointing to the location of a piece of paper placed beneath the hands to protect the dial. Used photographic film is also satisfactory for this purpose. Cut a slit in one side of the paper, as shown, to get it placed properly. The hand remover illustrated is the type generally used. Check each hand as you remove it for tightness. Looseness indicates wear. Put the hands in a separate container.

Release Mainspring and Remove Movement

Turn the watch over, face down. Remove back (unscrew) and remove dust cover (snap fit). Release the mainspring; that is, release the unused power still stored up in it. To do this, hold the crown firmly with the thumb and first two fingers of one hand and release the click with a small, pointed tool held in the other hand, as illustrated in figure 12-3. Then let the crown rotate slowly between the thumb and the index finger until power in the spring is completely released.

Next, remove the two case screws and loosen the detent screw. With the thumb and fingers, remove the crown and stem (fig. 13-3). Retighten the detent screw and remove movement from the case.

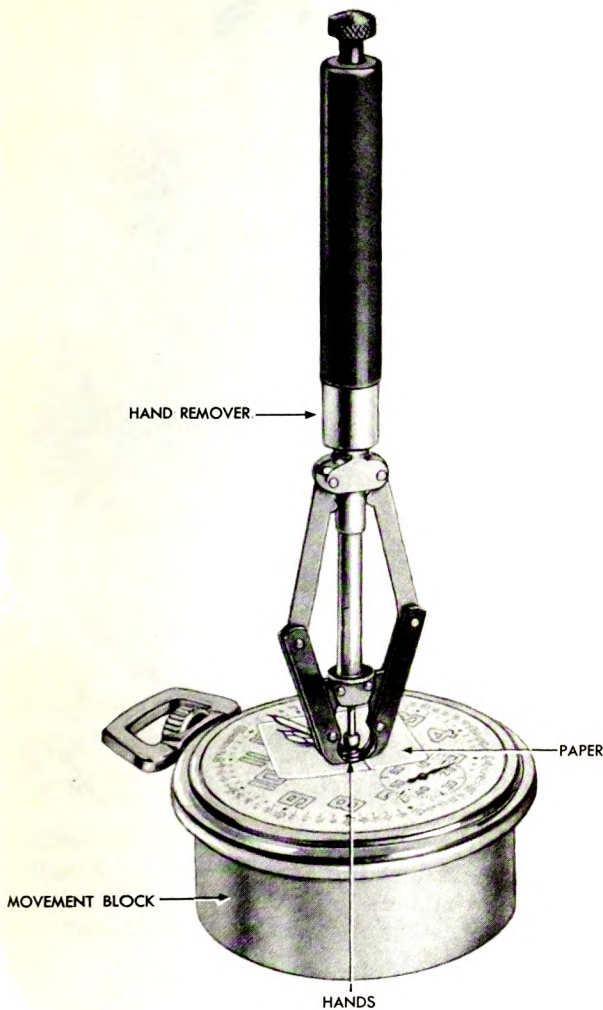


Figure 13-1.—Removing watch hands with a hand remover.

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Remove Dial and Dial Train

Turn movement over on the movement block, face up, and loosen three dial foot screws on the edge of the pillar plate. With the aid of a screwdriver, lift the dial off the face. Reset the dial foot screws. If you put the screws back into position, they will not be lost.

To remove the dial train, remove the hour wheel (lift off with tweezers) and the cannon pinion. Use a cannon pinion remover to remove the cannon pinion. Study figure 13-4.

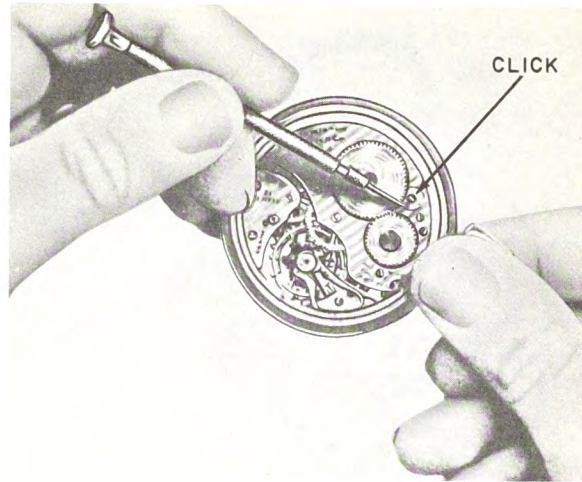


Figure 13-2.—Releasing power of the mainspring.

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Remove Balance Cock and Balance Assembly

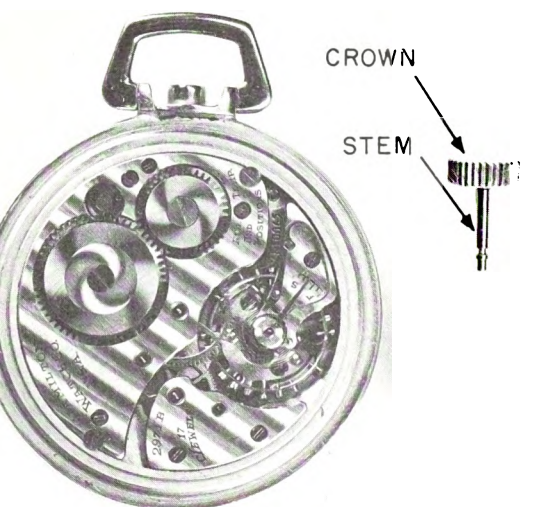
Reverse the movement in the movement holder (fig. 13-5) and loosen the hairspring and stud screw. Then use a screwdriver to loosen the stud. Remove the balance cock screw and take off the balance cock assembly. If it is tight, insert a screwdriver in the slot beneath and pry gently. Reset the hairspring stud screw. Place the balance cock assembly upside-down on a piece of pithwood and remove the two endstone cap screws. Turn the assembly over and remove the two regulator spring screws. Then lift off the regulator spring and assembly.

Use tweezers to lift the balance assembly from the movement. (See figure 13-6.) Put it in a separate container for safeguarding.

Next, remove the two pallet fork bridge screws and take off the pallet bridge and fork (fig. 13-7). Place these in a separate container.

Remove Major Mechanisms

First, remove the winding wheel screw (right hand screw on Hamilton 2974B) and the winding wheel. Then remove the ratchet wheel screw and the ratchet wheel, the click screw, the click and the click spring. Check these parts in figure 13-8. Put all parts in the proper basket or container.

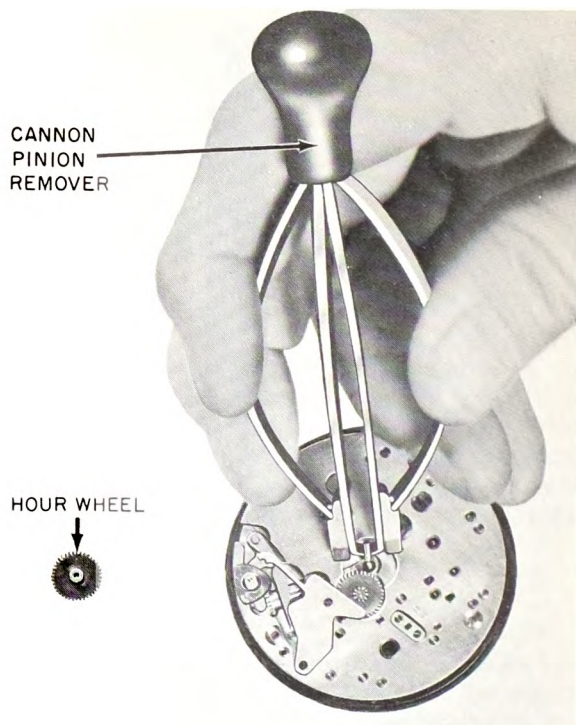


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Figure 13-3. -Crown and stem removed.

Remove next the barrel bridge screws, the barrel bridge, the barrel, and the center and third wheels. Then remove the lower wind-wheel. See figure 13-9.

To remove the barrel cap, the barrel arbor, the mainspring set the barrel assembly on a piece of pithwood or a bench block. Remove barrel cap by inserting a small screwdriver in the slot provided for that purpose, and gently pry the cap loose. Remove the barrel arbor by fully disengaging the arbor hook from the mainspring with a pair of tweezers and lifting it out. Remove the mainspring by grasping the arbor coil with tweezers and slowly pulling it out of the barrel, allowing it to uncurl as it comes out. Be careful NOT to distort the mainspring and handle it with bare fingers. Study figure 13-10. Remove the fourth wheel bridge screws and the fourth wheel free (fig. 13-11). Then take out the escape wheel. Next, remove the two hands setting bridge screws and lift off the hands with tweezers. Then remove the seconds setting lever and spring by lifting out the lever holding the spring with a piece of pegwood in order to prevent the spring from flying out. Next, remove the winding and setting mechanism. Remove first the two setting cap spring screws and the setting cap spring. Then remove the hands spring and lever. When doing this, use a piece of pegwood cut with a 45° angle flat edge to prevent the spring from snapping out of its position. (Spring is on dial side.)



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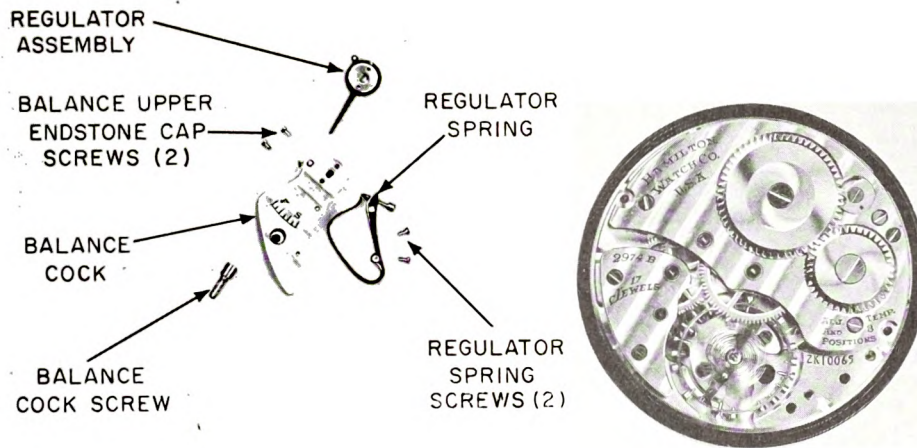
Figure 13-4.—Removing the cannon pinion.

You can now take out the two intermediate setting wheels and the minute wheel. Finally, remove the balance lower endstone cap screws and the balance lower endstone cap. Check these parts in figure 13-12.

CLEANING PROCEDURE

For cleaning watch and clock mechanisms, use the cleaning solution purchased and stocked by the Navy for this purpose. It is prepared in accordance with Navy specifications. (MIL-S-16553, Class I). When this cleaning solution is not available through regular Navy supply channels, procure a good commercial watch cleaning solution.

The next important consideration in cleaning watch and clock mechanisms is the method to be used. Should you clean each part by hand, or should you segregate them according to size and clean them in an instrument cleaning machine? The Navy uses both methods. The hand method is not used much for cleaning watch parts in instrument shops, but it must be employed for cleaning large clock parts which cannot be cleaned in an instrument cleaning machine.



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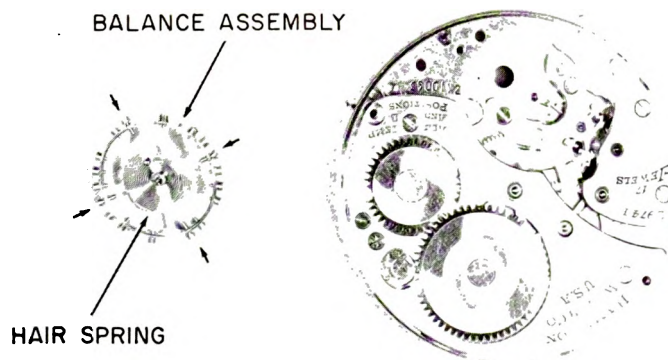
Figure 13-5.—Balance cock assembly removed and disassembled.

Hand Cleaning Method

Once jewelers sized watch parts, strung them on wires; dipped them in a cleaning solution; hand cleaned them with a brush; washed them in hot, soapy water; and then bathed them in alcohol. This procedure is still followed for cleaning some clock parts.

The recommended procedure, however, for cleaning by hand is:

1. Prepare the cleaning solution as recommended by the manufacturer; that is, use the recommended number of baths for cleaning and rinsing.



↑ MEANTIME SCREWS (4)

61.94

Figure 13-6.—Balance assembly removed.

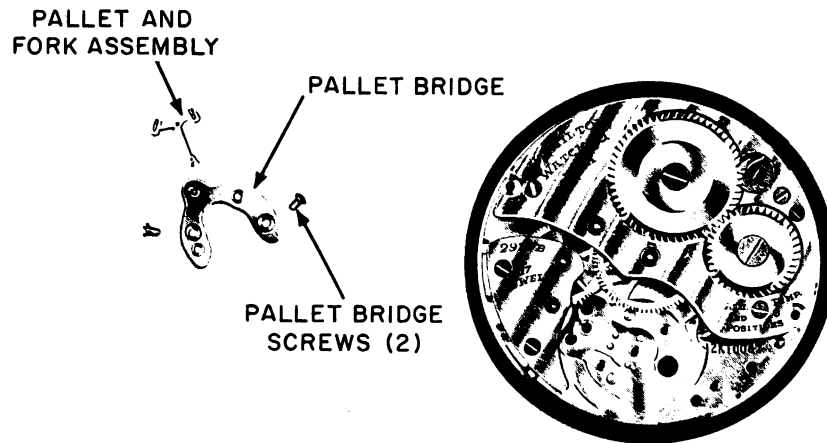


Figure 13-7.—Pallet and fork assembly removed.

61.95

2. Hand clean all large parts with a small, soft bristle brush.

3. Rinse parts in the rinsing solution.

4. Dry the parts and put them into a container for safekeeping until needed during re-assembly.

Machine Cleaning Method

The machine cleaning method is faster than hand cleaning and is just as satisfactory. The

machine revolves watch parts in a wire basket, agitating the cleaning solution, which dissolves grease and dirt from the parts. Generally, no follow-up hand cleaning is necessary.

One type of watch cleaning machine is illustrated in figure 13-13. (Note: Another type of cleaning machine is shown in chapter 6 of this rate training manual.) Note construction of the machine and the assortment of wire mesh baskets for different sized parts. Some baskets

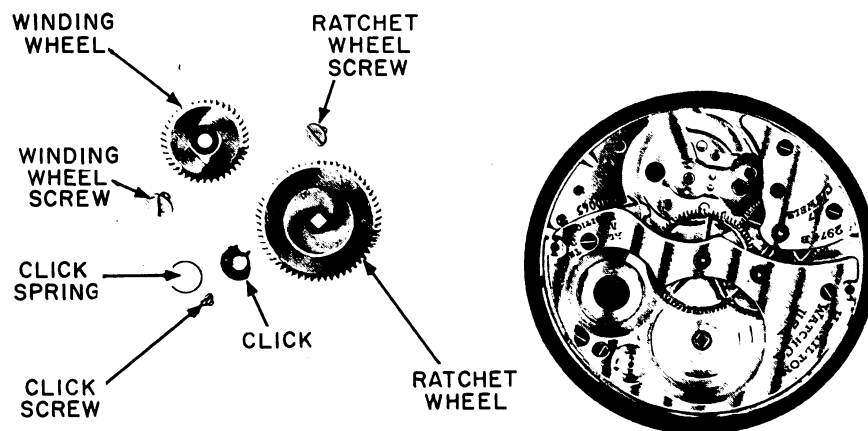


Figure 13-8.—Winding and ratchet wheels removed.

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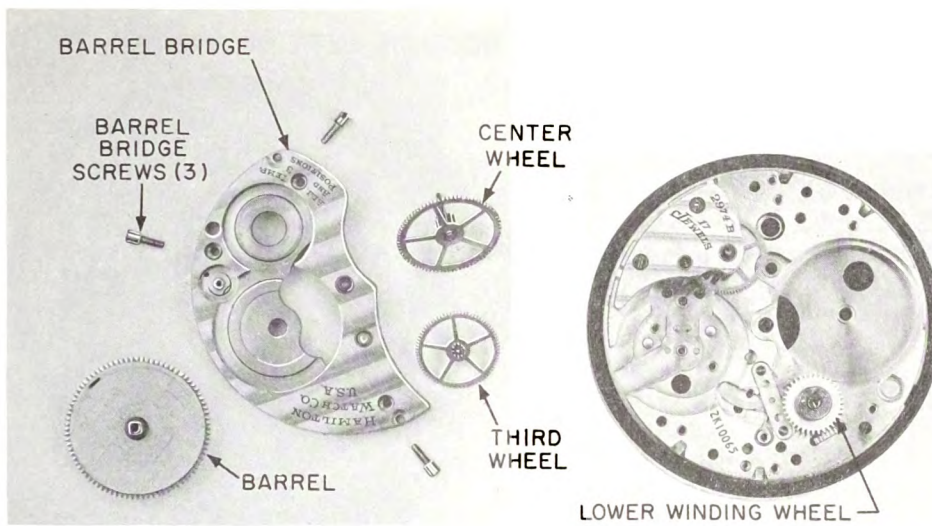


Figure 13-9.—Barrel bridge, barrel, center and third wheels removed.

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have subdivisions for keeping small parts separated from larger parts to prevent blemishes and damage.

The recommended procedure for cleaning watch parts with a machine is:

1. Put the dial train, winding ans setting parts, pallet, train wheels, and all other smaller parts into compartments of proper size.

2. Put the balance assembly in a separate container. (Some jewelers clean this by hand.)

3. Clean the mainspring by hand with a brush, or put it into a separate basket compartment. Be careful not to distort its shape during the cleaning process.

4. Put the cleaning and rinsing solutions in numbered jars, in the order recommended by the manufacturer.

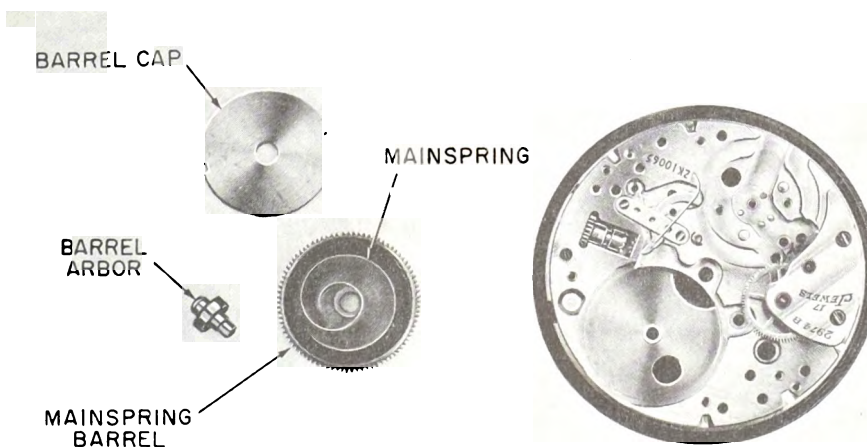
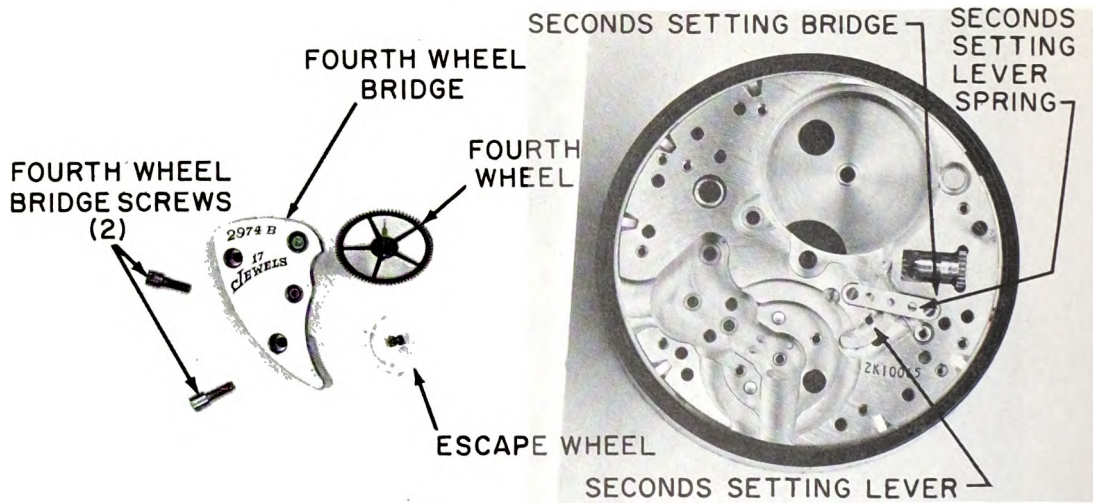


Figure 13-10.—Barrel cap and barrel arbor removed.

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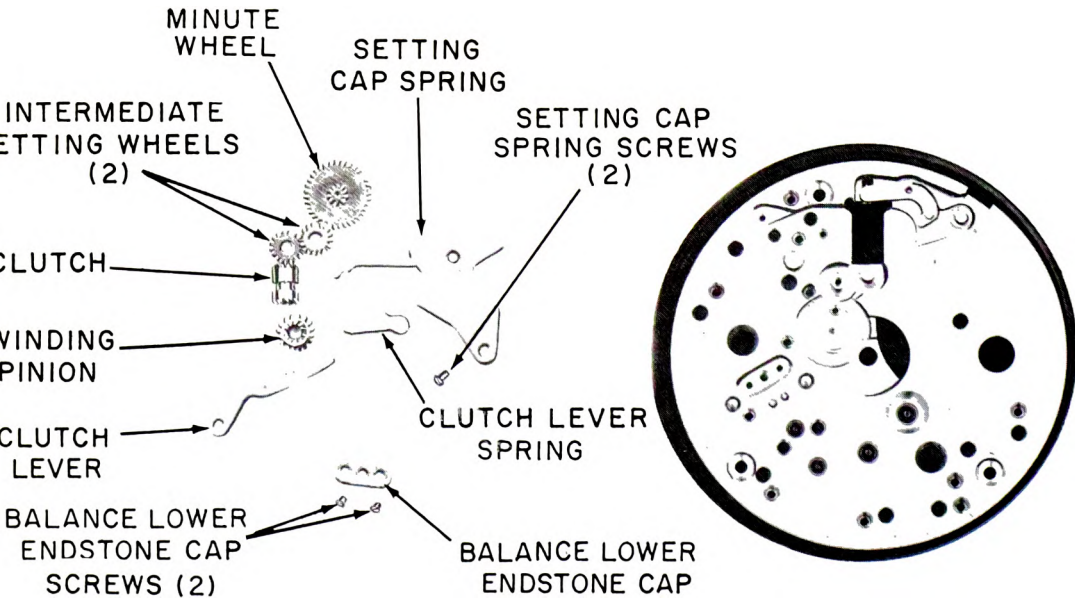
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Figure 13-11.—Fourth wheel bridge, fourth wheel, and escape wheel removed.

immerse a basket of parts in the cleaning solution and start the motor. Run the machine for 2 minutes, or as long as recommended. After the cleaning run, stop the motor 2 or 3

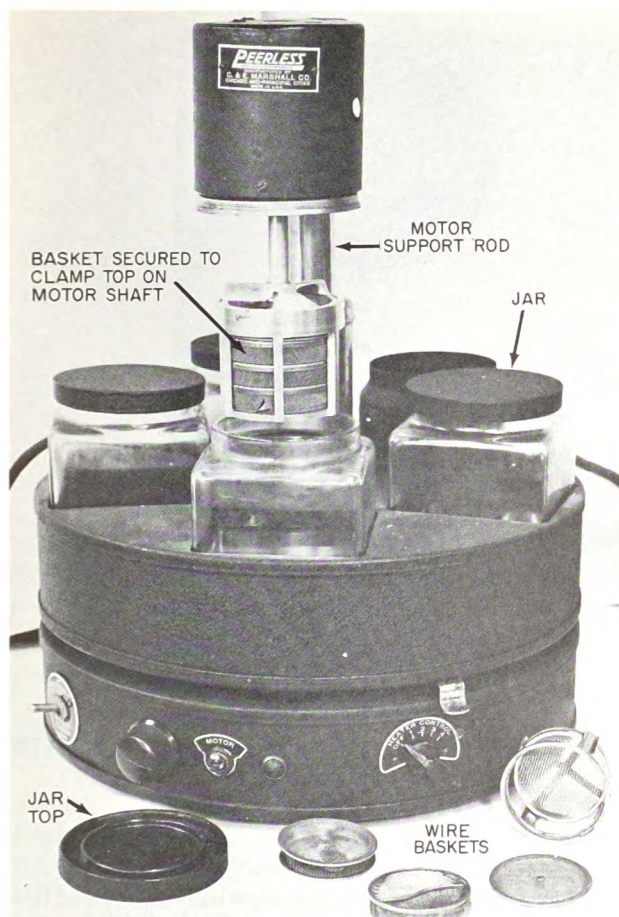
times to allow air to escape from the basket of parts. Air hinders cleaning.

6. Raise the basket of parts above the cleaning solution (basket should not touch solution)



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Figure 13-12.—Winding and setting mechanisms and lower endstone cap removed.



61.101

Figure 13-13.—Watch cleaning machine.

and revolve the basket about 30 seconds to remove excess solution from the parts and prevent soiled cleaning solution from getting into the second solution.

7. Immerse basket of parts in the second solution and proceed as with the first solution.

8. Repeat the process for jar number three, or as recommended.

9. Put the basket of parts into the drying compartment of machine and dry for recommended time.

10. Remove the basket of parts from the drying compartment and take parts from the basket. Remove each part separately with tweezers, and check for foreign matter. Handle with care. Your hands should be clean.

11. Remove and clean each cap jewel. Clean jewel holes with a piece of pegwood. Rub each jewel with a clean cloth before you replace it.

12. Tag blemished or damaged parts, or put them into separate containers.

13. Clean watch case by hand.

REASSEMBLING AND OILING

Regardless of all efforts to keep dust out, dust gets into the mechanism of a watch. After a definite period of use, oil in watch jewels and bushings evaporates, causing friction and wear of moving parts. For these reasons, watches (as well as clocks) should be cleaned and oiled periodically in accordance with manufacturer's instructions.

Reassembling and oiling of a watch must take place simultaneously, for this is actually the only time you can reach the parts to oil them. This means that you must know which parts of a watch require lubrication. In oiling, use Lubricating Oil, Watch (MIL-L-3918). It is used in 1/2-ounce bottles. It is very expensive, so be careful not to waste it.

Watch Oilers

You need the right types and sizes of watch oilers to oil watch parts adequately. Check the three types illustrated in figure 13-14. Each one has a tubular protector for its tip when the oiler is not in use. An oil cup with cover is also shown.

A watch oiler consists of a thin wire attached to a handle. Its tip is flattened to help retain oil when you dip it into the oil cup. To increase the holding capacity of a new oiler, some jewelers put a few small grooves in it with a file. Unless you use the right size of oiler for a particular jewel or bushing or part, you may apply too little or too much oil. Through experience, you will learn what size oiler to use for every part of the mechanism. Cover the oil jar when not in use to prevent evaporation or contamination with foreign matter. Push the tips of oilers into the pithwood to clean them, and protect tips with the tubular protectors when not in use.

Parts Which Require Oil

Watch parts which require oil are: (1) mainspring, barrel arbor, and winding parts; (2) upper and lower bearings of center staff; (3) upper and lower bushings or jewels of train wheels and the escape wheel; (4) upper and lower jewels of pallet; (5) faces of pallet jewels; (6) cap jewels; and (7) friction surface between center wheel arbor and the cannon pinion.

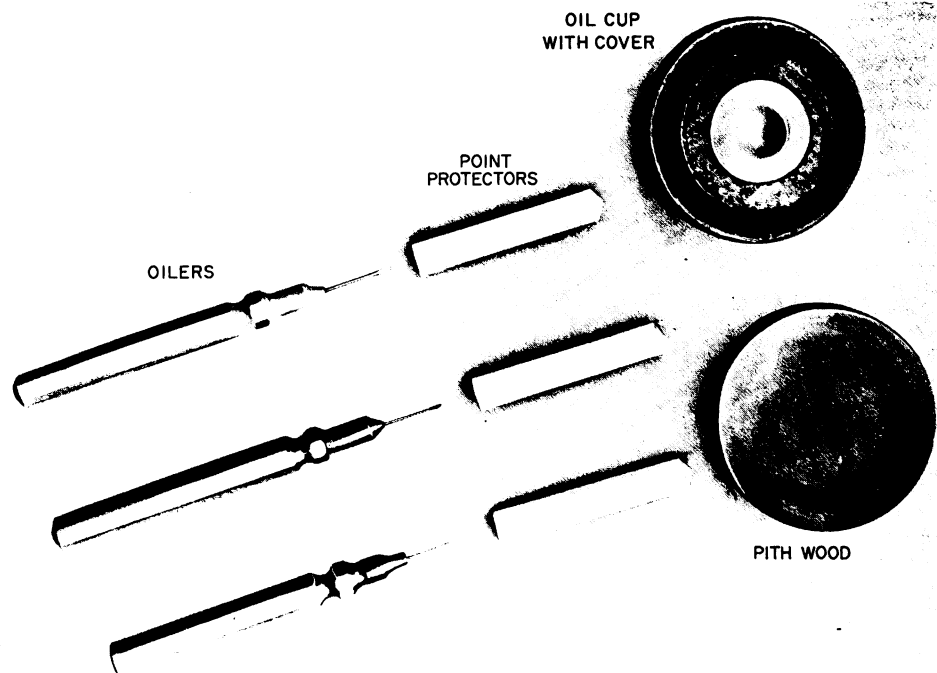


Figure 13-14.—Watch oilers and cup.

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Do NOT oil the following watch parts: (1) dial train wheels; (2) hairspring; (3) teeth of pinions of center, third, and fourth wheels; and (4) the roller jewel. Oil on the hairspring causes the coils to stick together and makes the watch run faster. The wheels mentioned move so slowly that they create very little friction and thus require no lubrication.

OILING PROCEDURE DURING ASSEMBLY.—

The following sections discuss the procedure for reassembling the mechanism of a watch into its case, and specify which parts to oil during the process. Assembly procedures are for the Hamilton Comparing Watch, model 2974B.

BALANCE HOLE JEWEL.—The balance hole jewel is not removed from the pillar plate of a Hamilton Comparing Watch during disassembly, but the bottom cap jewel is removed at this time. The first step in reassembling is to replace the bottom cap jewel and tighten the two balance cap jewel screws.

With an oiler of appropriate size, insert a drop of oil in the jewel hole cup. Push it down into the hole with a clean piece of polished wire,

as indicated in figure 13-15. Use an eye loupe to check the size of the oil bubble between the two jewels. If it seems too small, insert a little more oil and recheck. Continue in this manner until the oil bubble looks like the one shown between the two properly oiled jewels in figure 13-15. Do NOT allow the oil to touch jewel settings, as this results in the oil's being drawn away from the jewel bearing by capillary attraction.

Replace the seconds setting lever and spring. Replace the seconds setting bridge and two (2) screws.

ESCAPE AND FOURTH WHEELS.—Replace first the escape wheel and then the fourth wheel. Recheck figure 13-7. Then set the fourth wheel bridge in place over the two wheels. Use tweezers or an appropriate tool to work the wheels into their proper operating positions. Then replace the two fourth wheel bridge screws and tighten them. Test wheels for freedom of movement and endshake (.02 mm tolerance).

MAINSRING ASSEMBLY.—Select a main-spring winder of proper size and wind the

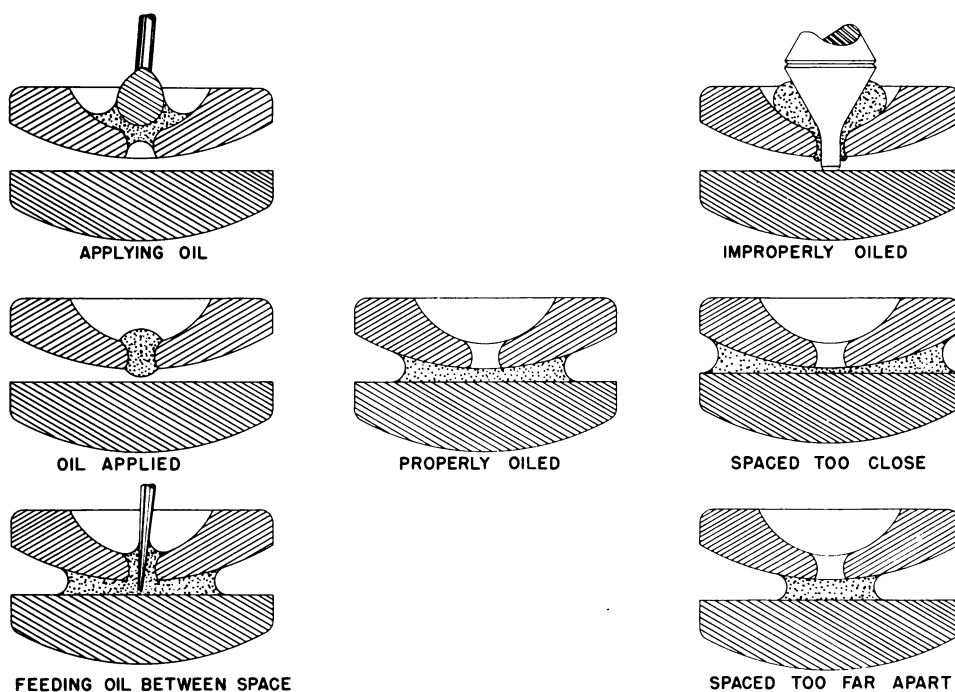


Figure 13-15.—Correct procedure for oiling a balance jewel.

61.103

mainspring into it. Leave the last inch of the mainspring protrude from the winder in order to facilitate the fastening of the mainspring to the barrel. Place the barrel over the winder and hook the end of the mainspring to the barrel. Then press the mainspring out of the winder into the barrel. Apply a small amount of oil to the shoulders of the barrel arbor and insert it into position. Hook the inner end of the mainspring onto the barrel arbor (fig. 13-16). Apply about five small drops of good clock oil to the edge of the mainspring. Line up the barrel cap over the "T" end of the mainspring and press it into place. Then check the arbor for freedom of endshake.

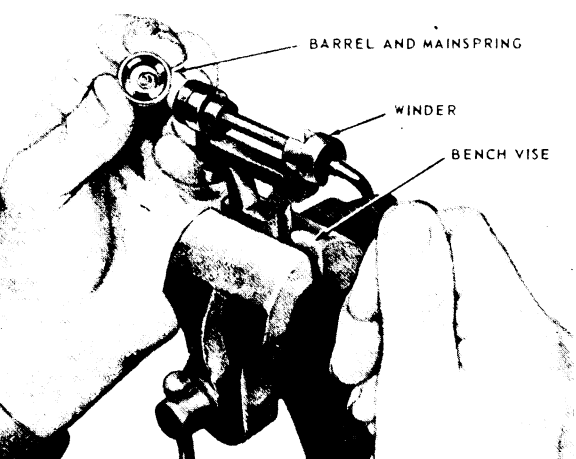
BARREL ASSEMBLY AND BRIDGE.—Insert the barrel first; then replace both the third and center wheels. Lubricate and assemble the upper and the lower winding wheels on the barrel bridge and replace the bridge. Gently work the pivots into place. Insert and tighten three barrel bridge screws and test wheels for freedom and endshake.

SETTING AND WINDING MECHANISM.—Replace the click spring, the click, and the click

screw. Replace the ratchet wheel and the ratchet wheel screw, and loosen the detent screw. Invert the movement, dial side up, and replace the winding pinion in its slot and the clutch wheel in its proper position. Oil the staff on the stem, and replace the stem in the movement. Tighten the detent screw, which holds the stem in place. Replace the clutch lever and the spring. Use a piece of pegwood to hold the spring while you work it into place. Replace the two intermediate setting wheels and the minute wheel. Then replace the setting cap spring and tighten the screws. Add a small drop of oil to the end of the setting cap spring.

Oil the pivots of the center, the third, the fourth, and escape wheels. At this point, check the freedom of movement of the train. Wind the mainspring one full turn and watch the action. If the wheels of the train backlash at the end of winding, the train has perfect freedom, but if they stop abruptly or slow down, a bind exists in the movement.

PALLET AND BRIDGE.—Oil the pallet stones on their impulse faces. Replace the pallet fork in the pillar plate, and then put on the bridge.



61.104

Figure 13-16.—Watch mainspring winder.

carefully align the pallet arbor pivot in its hole and insert and tighten pallet bridge screws. Now check the pallet assembly for freedom of action. To do this, wind the mainspring two turns and serve the movement.

BALANCE COCK ASSEMBLY.—Place the upper cap jewel upside down and position the regulator on top of it. Line up the two cap jewel screw holes and replace the screws. Invert the balance cock and lubricate the upper balance hole jewel (fig. 13-15). Replace the regulator spring and screws and loosen the hairspring stud screw. Replace the balance assembly on the balance cock and tighten the hairspring stud screw. Prevent oil from getting on the hairspring. Lift the balance cock, with the balance wheel attached, and gently work it into place in the movement. To do this, place the balance wheel under the center wheel and engage the roller jewel pin in the slot of the pallet fork. Then tighten the balance cock screw.

Oil the pallet stones on their impulse faces, apply oil to every other foot on the escape wheel. When the watch runs, the oil will then be distributed evenly on all feet of the wheel.

CANNON PINION AND MINUTE WHEEL.—Loosen three dial foot screws and invert the movement in the holder. Lubricate the center wheel arbor. Then position the cannon pinion on the center wheel and press it into place. Be sure the cannon pinion meshes with the minute wheel. Check to determine that the pinion has the same amount of friction all around.

HOUR WHEEL.—Set the hour wheel in place on the cannon pinion. Make certain that it meshes properly with the pinion of the minute wheel.

DIAL AND HANDS.—Now replace the dial and tighten the dial foot screws. Then put the hour hand in place, pointing to 12 o'clock, and press it down. Follow with the minute hand, also pointing to 12 o'clock. Install next the second hand. Then check all around for clearance of each hand with the other hands.

FINAL ASSEMBLY.—Loosen the detent screw and remove the watch stem and crown (fig. 13-3). Carefully put the movement into the case band and replace the stem and crown. Tighten the detent screw. Replace and tighten the two case screws. Replace the bezel, back dust cover, and the back. The job of reassembling is now complete.

MAINTENANCE OF CLOCKS

This section tells you how to disassemble a clock mechanism, how to clean various parts, and how to reassemble and oil parts.

Additional information concerning maintenance and repair of clocks, as well as individual parts, can be obtained from either Instrumentman 1 & C, NavPers 10194-B or manufacturers' technical manuals for specific types of clocks.

DISASSEMBLY

The purpose of disassembly is to break down the clock movement to the extent required for proper inspection and cleaning, and repairing as necessary. If the movement is not broken down in accordance with recommended procedure, incomplete inspection and improper cleaning result. On the other hand, if you break down the movement to a greater extent than necessary, you make extra work for yourself. For these reasons, proper disassembly is an important part of clock repair. Never work on clocks with luminescent dials or hands. Refer to SPCC (Ships Parts Control Center) INST 9870.1.

Always completely overhaul a clock whenever it: (1) receives physical damage, (2) will not run, and (3) fails to keep good time. These symptoms indicate mechanical trouble which should be remedied immediately in order to prevent more extensive damage. The general

rule for overhauling a clock is: IF POSSIBLE, COMPLETELY OVERHAUL EACH CLOCK ONCE PER YEAR; EVERY CLOCK MUST BE OVERHAULED AT THE END OF A TWO-YEAR PERIOD. This rule always applies, even though a clock appears to be in perfect working condition. The reason for this is that foreign matter or gummy oil causes damage to parts which run at rapid speed, such as the balance wheel, which swings 300 times each minute.

The overhaul procedure for clocks is normally broken down into disassembly, cleaning, escapement operation, reassembly (no repairs required), testing, and adjusting. Repairs, of course, must be made as required, including the replacement of parts, which is the general rule.

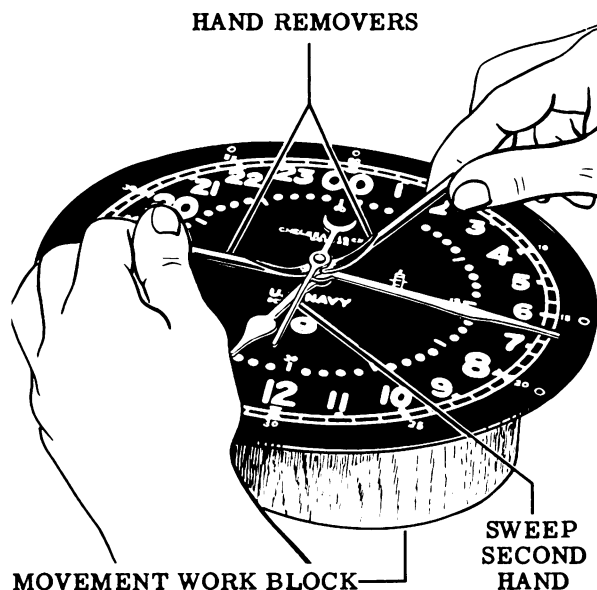
When clocks are brought to the instrument shop for overhaul and repair, place each clock in one of three categories:

1. Operating condition—sent in for routine cleaning, oiling, and adjusting.
2. Non-operating condition—clock has not met with an accident.
3. Accident damaged mechanism—mechanism of such a clock should be inspected closely during cleaning, to determine the extent of damage, and to decide what action to take with respect to it.

Preliminary Disassembly

The removal of a clock movement from its case and the removal of hands and dial components from the movement constitutes preliminary disassembly. The purpose of this phase of disassembly is to enable you to make a preliminary inspection of the movement. The procedure for doing this work follows:

1. Unscrew the case knob which secures the bezel to the case and swing the bezel open.
2. Remove the three reflector screws which hold the reflector on the dial and the movement in the case.
3. Place a winding key or mainspring let-down key in the dial winding hole and lift up (with tilting and twisting motion) one edge of the dial enough to enable you to grasp it with your fingers.
4. Remove the movement from the case and pit it (dial side up) on a movement work block.
5. Use a pair of hand removers (with felt pads) to pry off the hour, minute, and second hands (fig. 13-17).
6. Tilt the dial and movement sufficiently to enable you to remove (with needle-nose pliers)



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Figure 13-17.—Removing hands from a clock.

the grasshoppers which hold the dial. See figure 13-18. Then pull the grasshoppers off the dial feet.

7. Lift off the dial with the attached dial ring.

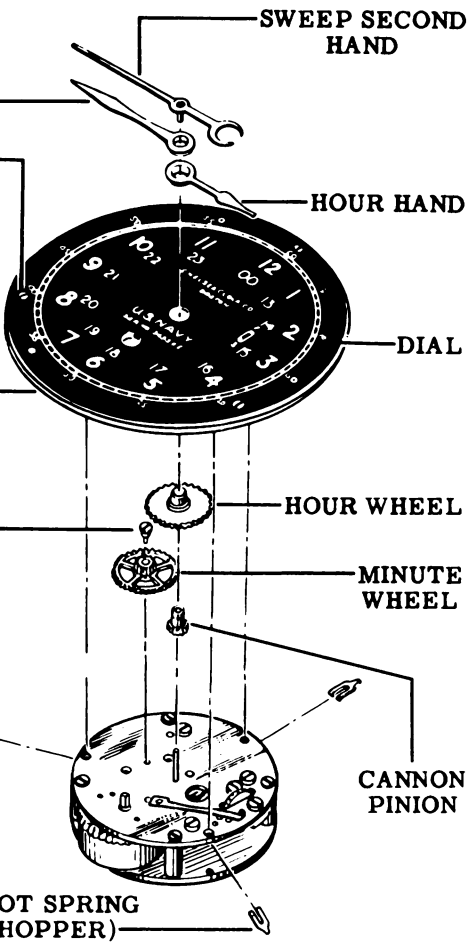
Observe in figure 13-18 the position of the hour and minute wheels and the cannon pinion. Perpendicular lines indicate where they fit on the plate.

Pre-disassembly Inspection

Preliminary (pre-disassembly) inspection of a clock movement follows preliminary disassembly. The purpose of this inspection is to determine whether the movement is worth overhauling and to locate trouble within the movement. (Further inspection of mechanisms and parts takes place during cleaning and re-assembling.) Difficulties located during the preliminary inspection should be entered on a route ticket, to make certain that they will be found and corrected during regular overhaul and repair. The preliminary inspection also affords an opportunity for recording statistics on the performance of clock components.

The procedure for making a preliminary inspection follows:

1. Check the clock movement for gumming of oil, corrosion of parts, and physical damage;



91.241

Figure 13-18.—Removing grasshoppers from dial feet.

all parts you can see and examine at of disassembly.

Check the cannon pinion for clearance front plate.

Test the tension of the click spring. Check all parts for clearance, and screws tightness.

Based on the findings of your inspection, make a decision as to whether the clock should be repaired or surveyed, and parts salvaged. Indicate on your job order the specific parts to be checked and your recommendations for replacement during inspection. Justify when reassembly is accom-

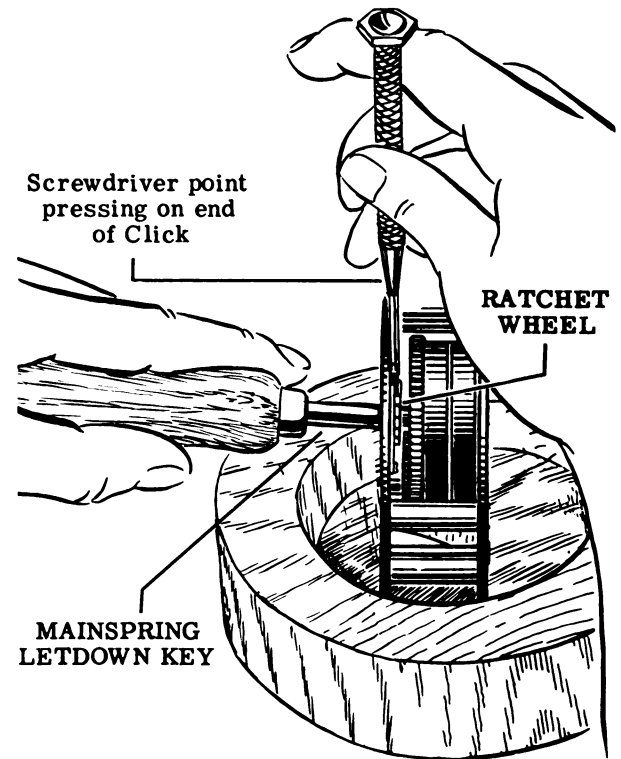
7. Enter on the job order your recommendations for the escapement relative to replacement. Enter the names of specific parts which should be checked.

Disassembly of Movement

During disassembly of a clock movement, put all parts in cleaning trays as you remove them. This action is necessary in order to prevent loss of or damage to parts.

The first step in disassembly is release of the mainspring. To release the spring, put the movement on its side in a work block, as shown in figure 13-19. Then place a mainspring let-down key over the square end of the barrel arbor and turn it about 1/8th turn clockwise while you disengage the click from the ratchet wheel on the barrel arbor with a small screwdriver held in the other hand.

Turn the movement dial side up in the work block and unscrew the minute wheel screw and



91.242

Figure 13-19.—Releasing power of clock mainspring.

remove the minute wheel. Then use hand removers with felt pads (fig. 13-20) and remove the cannon pinion from the center arbor.

Next, turn the movement over (back plate up) and unscrew the four backplate screws. Then remove the back plate and lift out the mainspring barrel assembly and ratchet wheel. Study figure 13-21.

To remove the barrel cap, hold the barrel in one hand and lightly tap the end of the barrel arbor which protrudes farthest through the cap with a wood or plastic hammer (NOT STEEL). The shoulder on the arbor transmits the force of the hammer to the cap and drives it out. Then remove the barrel arbor hook.

Place the barrel (with mainspring) on a mainspring winder and engage the inner end of the mainspring with the hook on the turning shaft of the winder. Wind enough spring on the winder to provide sufficient space inside the barrel for the portion of the winder which holds the outer turn of the mainspring.

When the mainspring is securely held by the winder, turn the barrel back and forth to dis-

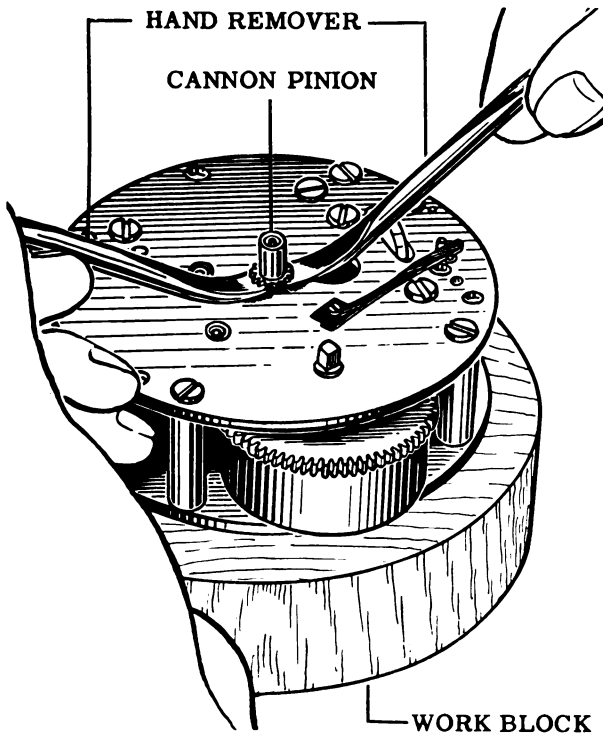


Figure 13-20.—Removing a clock cannon pinion.

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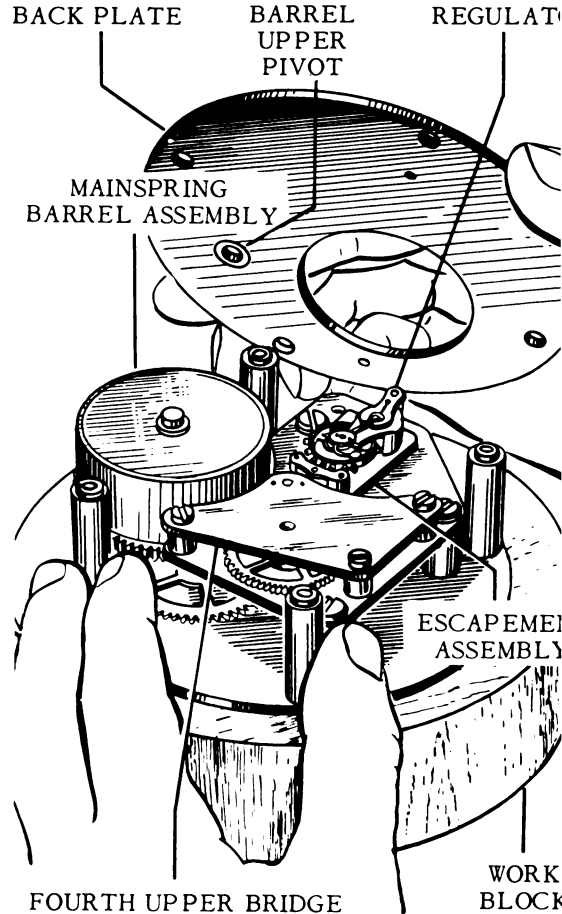


Figure 13-21.—Removing back plate from clock movement.

engage the outer end of the mainspring from barrel hook. Pull off the barrel. Then hold winding handle of the winder and release click, but prevent the spring from unwinding. Unwind the mainspring by slowly turning handle of the winder. As you unwind the spring pull on the outer end to get it out of the barrel.

NOTE: DISCARD the OLD mainspring, unless circumstances require that it be reused.

(The mainspring barrel and its components are illustrated in figure 12-26.)

Next, unscrew the fourth upper bridge screw and remove the fourth upper bridge (fig. 13-21).

Insert a screwdriver through the work hole in the front plate and unscrew the two escapement mounting screws. Then the escapement is removed and disassembled, in accordance with recommended procedures. (NOTE:

ures for disassembling, cleaning, lubricating and reassembling clock escapements are found in Instrumentman 1 & C, NavPers 1000-B. Additional information concerning maintenance of escapements can be obtained from technical manuals for specific equipment.) The parts to be disassembled are removed, all parts of the case components, including the dial, hands, and the escapement, now be in the parts tray. All parts of movement, except the escapement, should be in the cleaning tray.

CLEANING PROCEDURE

It is impossible to lubricate a clock properly if the movement is not perfectly clean. Even a thin film of oil causes oil to spread, leaving pivots and jewels subjected to unnecessary wear. Oil or grease (especially if dust-contaminated) on

pivots and other moving parts causes wear, erratic operation, and loss of power. Because the balance wheel of an average timepiece swings 157,680,000 times each year, and other wheels swing in proportion, one microscopic grain of grit in bearings or on pivots can be injurious.

During the pre-disassembly inspection, you make notations of defects in parts on the job order. Recheck the parts on which you made notation, and also check other parts which you could not inspect closely during inspection. Do NOT clean parts which are worn, damaged, or badly corroded—REPLACE THEM WITH NEW PARTS. Before you clean parts in a cleaning machine, be sure to remove gummy residue from bushings with pegwood.

If suitable sealed containers are not available for stowing cleaned parts, do NOT clean them MORE THAN ONE DAY in advance of reassembly. This rule is MANDATORY.

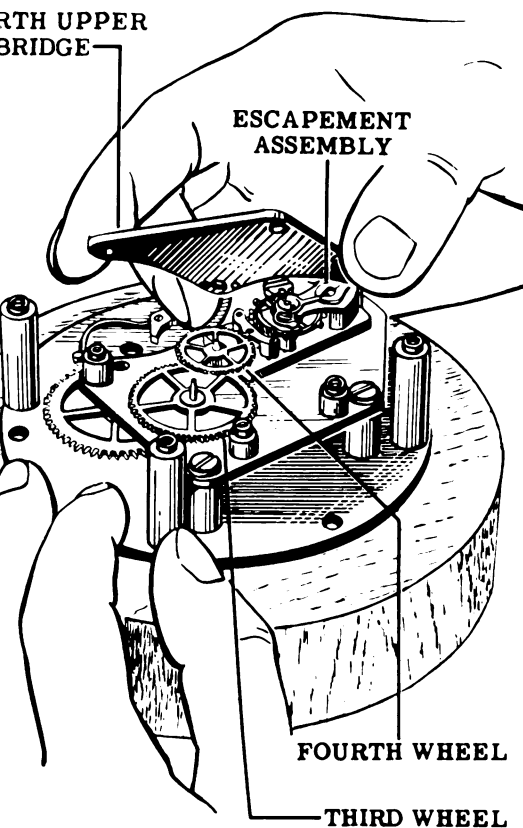
Cleaning by Machine

At one time many clock parts were cleaned by hand. This method was adequate, but it was a slow, painstaking task (process). Through experience, Instrumentmen learned that machine cleaning of watch and clock parts is fast, requires little skill, and is satisfactory. By the machine method, all clock parts can be cleaned at the same time. The ONLY parts you need to clean by hand are dials, hands, cases, mainsprings, and plates.

Review the description and operating procedures of the machine discussed earlier in the chapter (fig. 13-13). In addition, review the machine discussed in chapter 6 of this manual, and study the figures which show an assortment of wire mesh baskets for different sized parts, and how clock parts should be placed in the basket for cleaning.

CAUTION: If you leave clock parts in the cleaning and rinsing solutions longer than recommended, you may etch them.

Use tweezers to handle clean watch and clock parts. Use hand operated air bulb or remove lint with tweezers. (NOTE: DO NOT USE COMPRESSED AIR HOSE; this results in the loss of parts and can also result in distortion of the hairspring.) Check parts for remaining residue, especially inside bushings and pivots. If necessary, clean the bushing with a soft piece of pegwood, and press the pivots into clean pith.



91.245

Figure 13-22.—Removing the fourth upper bridge.

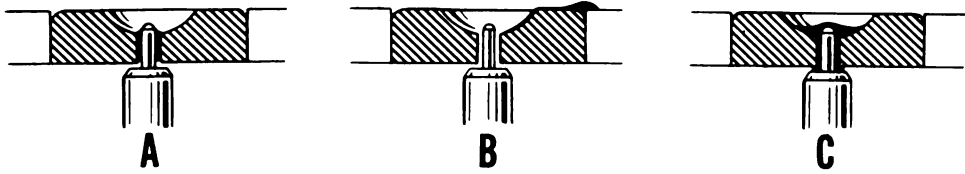


Figure 13-23.—Proper way to oil a bearing.

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Stow clean clock parts in sealed or covered containers to protect them from foreign matter.

Cleaning by Hand

Use a clean, damp cloth to clean the dial, the hands, and the case of a clock. Remove dried oil or grease with a clean cloth dampened with naphtha or cleaning solution. CAUTION: Do NOT rub the dial numbers OFF, or the luminous dots next to the numbers.

If you must reuse a mainspring, remove gummed oil on it with a clean cloth dampened with naphtha or cleaning solution; then dry it with a clean cloth. NOTE: Work the cloth between the turns of the spring to ensure cleanliness of the entire surface. This rule applies to both cleaning and wiping.

Additional information concerning inspection and repair of clocks, after cleaning, can be found in Instrumentman 1 & C, NavPers 10194-B or in manufacturers' instruction books for specific clock parts.

REASSEMBLY AND OILING

As mentioned earlier in the chapter, the procedure for reassembling a clock or watch is accomplished in the reverse order of disassembling. Consult the manufacturer's technical manual for the timepiece concerned when you do this work, as necessary.

One important part of reassembly of a clock is the inspection of parts for fit and tightness. Another important aspect of reassembly is oiling, for at this time you can get to the places which require oil. For this reason, reassembly and oiling are considered together in this section.

Clock Lubricants

A good clock oil is an absolute necessity, but there is no such thing as a PERFECT clock

oil. Even the best types of oils have some undesirable characteristics; and for this reason, it is always best to use ONLY the lubricants recommended by the manufacturer or the Navy for a particular timepiece. A good clock oil does NOT:

1. Spread (draw away from pivots).
2. Become gummy during usage.
3. Evaporate from parts.
4. Oxidize or corrode metals.

Remember to keep your main supply of clock oil tightly covered and away from light, to protect it from foreign matter and the power of sunlight. Also, guard it against any type of contamination.

When oiling a clock, put a small amount of oil in an oil cup, preferably one with a cover, and protect it from dirt. Keep the cover on tight when you are not actually using the oil.

Proper care of clock oil cannot be over emphasized. Dirty oil causes abrasions on pivots and becomes gummy during use much faster than clean oil.

CAUTION: Because clock oil is cheaper than parts, it is best to discard unused oil from the oil cup at the end of each day's work.

You can make a clock oiler from a piece of steel wire, or use a good commercial one. A flat, notched point on an oiler is best; for the notch holds the oil at the tip of the oiler. It is also a good idea to push the oiler into a piece of clean pithwood before you dip it into the oil cup, not only to clean the oiler but also to enable you to judge better the amount of oil you get on the tip of the oiler.

Oiling Procedure (with Inspection)

The oiling of clock parts during reassembly (with necessary inspection) takes place in logical order. Before we discuss the various steps in the oiling and inspecting procedure, however,

test to stress the importance of the method used for oiling bearings and bushings.

When you oil a train bearing, ALWAYS OIL THE BUSHING and the PIVOT at the same time, for this causes the oil to flow through the bushing hole and around the pivot, as shown in part A of figure 13-23.

When you remove the oiler from a bushing, lift it straight up to avoid a track of oil across the bushing to the surrounding metal. If you do leave such a track, the oil is drawn from the pivot and out to the surrounding metal (part B, fig. 13-23). If you put too large a drop of oil in the bearing, the oil flows through the hole and over the pivot shoulder, the pinion, and through the teeth of the movement. See part C of figure 13-23.

You will recall that during disassembly the parts were left on the front plate because it was not necessary that they be re-oiled. You should therefore start to reassemble the clock mechanism by inspecting these parts, then continue with the oiling and inspecting procedure until the entire mechanism is

assembled. Inspection at this time is most important, because it is your last chance to check for blemishes and damage you previously overlooked (if any) during the overhaul and repair process. The parts in a clock mechanism which you should inspect and oil during reassembly are as follows:

1. Inspect the back plate pillars for tightness.
2. Check the click spring for the amount of pressure it exerts. If necessary, bend this spring to increase the pressure it exerts on the click, to ensure positive engagement with the barrel ratchet wheel.
3. Oil the corners of the center wheel friction spring.
4. Inspect for uprightness of the center and intermediate wheels in their pivot holes; test for tilt in four directions.
5. When you have the center and intermediate wheels in position, check them for freedom of action in their pivot holes. Check these wheels also for ENDSHAKE.

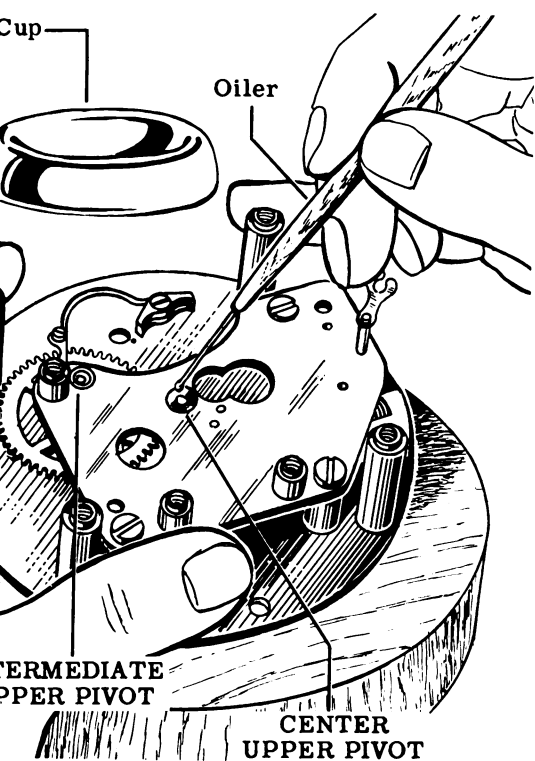


Figure 13-24.—Oiling upper pivots of center and intermediate wheels. 91.252

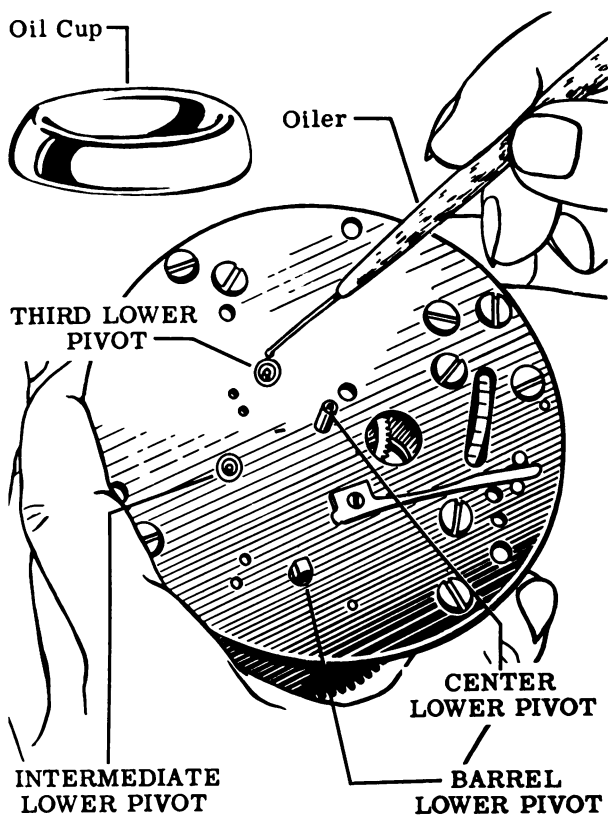


Figure 13-25.—Oiling lower clock pivots. 91.253

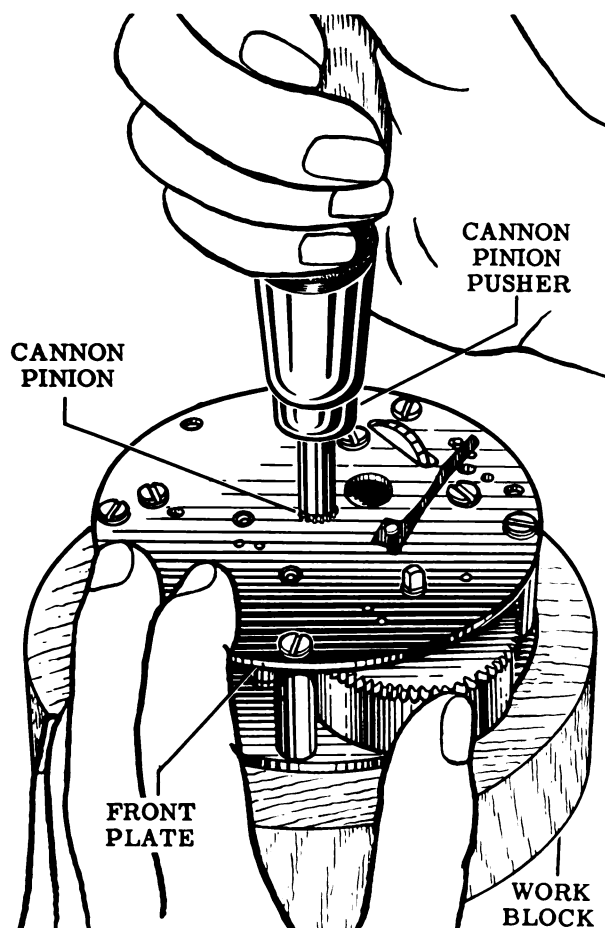


Figure 13-26.—Inserting a cannon pinion with a pusher.

6. Oil the upper pivots of the center and intermediate wheels. See figure 13-24.

7. After you have the fourth wheel in position, oil its staff.

8. Check for endshake and sideshake in the third and fourth wheels. Oil the upper pivots of these wheels.

9. When you have the mainspring wound into the barrel, use an oil can with a fine spout to apply a thin stream of oil across the edges of all coils, straight across the top of the mainspring. NOTE: Add the oil before you insert the barrel arbor. As the spring is wound later, the oil spreads evenly over the mainspring and

inside the barrel. CAUTION: If you use TOO MUCH OIL, it may be forced out of the barrel when the mainspring is wound tightly.

10. When you insert the barrel arbor, check for endshake and sideshake. Turn the arbor several times to make certain that the barrel hook and arbor hook engage the mainspring inside the barrel.

11. Oil the arbor bearings.

12. After you have the ratchet wheel in position, check the engagement of the click.

13. When the back plate is in position, oil the barrel upper pivot and the fourth upper pivot.

14. Put the clock movement dial side up in the work block and oil the center, third, and intermediate lower pivots (fig. 13-25).

The procedure for inserting the cannon pinion with a cannon pinion pusher is shown in figure 13-26.

Whenever you are in doubt about any part of a clock mechanism, or any procedure you take with respect to disassembly, cleaning, repairing, reassembly, oiling, and adjusting, ALWAYS refer to the manufacturer's technical manual for the clock on which you are working. The best plan is to follow this rule until you know the mechanism well enough that you can do the work without any questions in your mind.

Recheck the job order for the clock, to make certain that all recommendations pertaining to it have been initialed, indicating that the work was accomplished.

STORAGE OF TIMEPIECES

Stow watches and clocks where they are protected from dampness and extremes of temperature. A cabinet is good for this purpose. Keep new instruments in their original cartons, for added protection against knocks or jars, until they are needed. Used watches and clocks in storage should be tagged to indicate the age, cleaning, oiling, and repair dates, or other pertinent information. Stow them where they will be adequately protected from damage.

After Instrumentmen have repaired a watch or clock, they normally put it on a shelf (secured) or hang it on the bulkhead of the instrument shop to check its accuracy over several days of continuous running.

CHAPTER 14

REPAIR AND MANUFACTURING PROCESSES

This chapter deals with certain repair and manufacturing processes that you may be required to perform in connection with your duties as an Instrumentman. The chapter also includes information on some of the special tools and safety precautions required for these repair and manufacturing processes.

TOOLS

No mechanic can do satisfactory work unless he has appropriate tools for each job he may be asked to perform. For example, a carpenter must have different types of saws, chisels, hammers, screwdrivers, planes, levels, and squares. As an Instrumentman, you must have appropriate tools for working on all types of instruments and machines repaired in the instrument shop.

BASIC TOOLS AND MEASURING DEVICES,

As an Instrumentman, you will be required to use and care for a number of tools: drills, grinders, thread taps and dies, thread combs, files, feeler gages, micrometers, vernier calipers, dial indicators, and many kinds of screwdrivers and pliers, to name but a few. In addition to these rather common hand and power tools, and the watch and clock tools covered in chapters 12 and 13, you will also be responsible for using and caring for the specialized tools used for maintaining gages and instruments, typewriters, and other equipment that is the special responsibility of your rating.

Since many kinds of common hand and power tools are described and illustrated in Basic Handtools, NavPers 10085-A, these tools are not discussed in this chapter. Instead, we will concentrate on the tools that are special to the Instrumentman rating. In this connection, note one major point of importance: ALWAYS check

the manufacturers' instructions to find out what kind of special tools may be required for any particular job; then be sure to use the correct tools. If tools cannot be procured from a supplier, the only alternative is to draw a sketch or make a blueprint of the tools and make them in the machine shop.

TYPEWRITER REPAIR TOOLS

Because so many typewriters are used in offices aboard ship, and because of the extensive use of delicate parts in mechanisms in the machines, much cleaning, repairing, and adjusting must be done. To do this work satisfactorily, you must have special typewriter tools, and even special tools for certain makes and models of typewriters. The following sections explain various typewriter tools and their uses.

Screwdrivers

Screwdrivers should be used only for removing and inserting screws. If the blades are used for prying things loose, the blades may be damaged or the shanks twisted or bent.

SIZES AND TYPES.—Typewriter screwdrivers vary in width and shape of blade, length of shank, and overall shape. The length of blades and shanks combined is generally from 3 to 12 inches, and the width of blades varies from 1/8 inch to 5/16th inch. See figure 14-1 for some general purpose screwdrivers.

Special tools required to service particular models of typewriters are obtainable from typewriter manufacturers. Figure 14-2, for example, shows a screwholding screwdriver made by Smith-Corona, an offset screwdriver made by Remington Rand, and a Royal combination screwdriver.

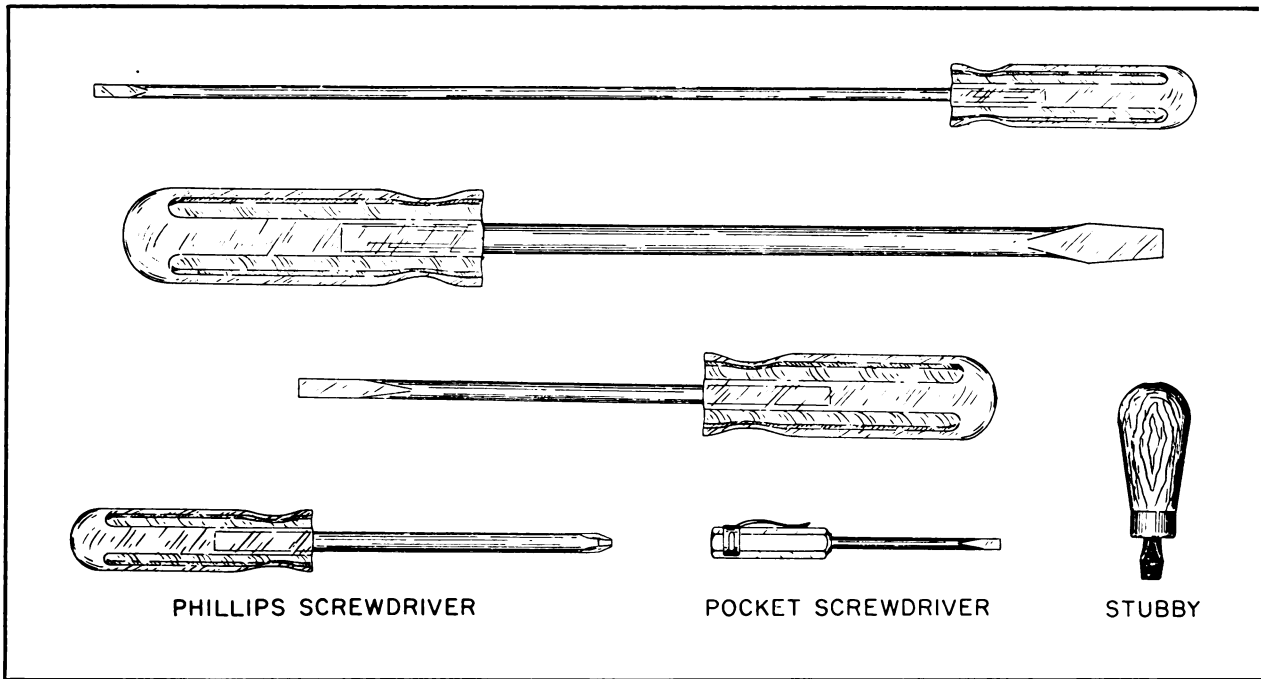


Figure 14-1.—Typical screwdrivers used in typewriter repair.

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PROPER CARE OF SCREWDRIVERS.—Always keep the blades of screwdrivers in good shape. The flat blade of a screwdriver may be dressed on a grinder. Use a 6-inch wheel to dress screwdrivers used for small screws. To dress the sides, hold the blade of a screwdriver high on the circumference of the wheel and rest the shank on the tool rest.

The thickness of a screwdriver blade at the end should be such that it will just enter the slot of the type of screw it is designed to drive, and the sides of the blade should be as nearly parallel as possible. Study figure 14-3. Next, square off the end of the blade. If the end of a screwdriver blade is square and of proper thickness, with sides parallel or nearly so, there is less likelihood of its climbing out of a screw slot when a little pressure is applied. A small, triangular file is good for removing burrs from the blade of a Phillips screwdriver.

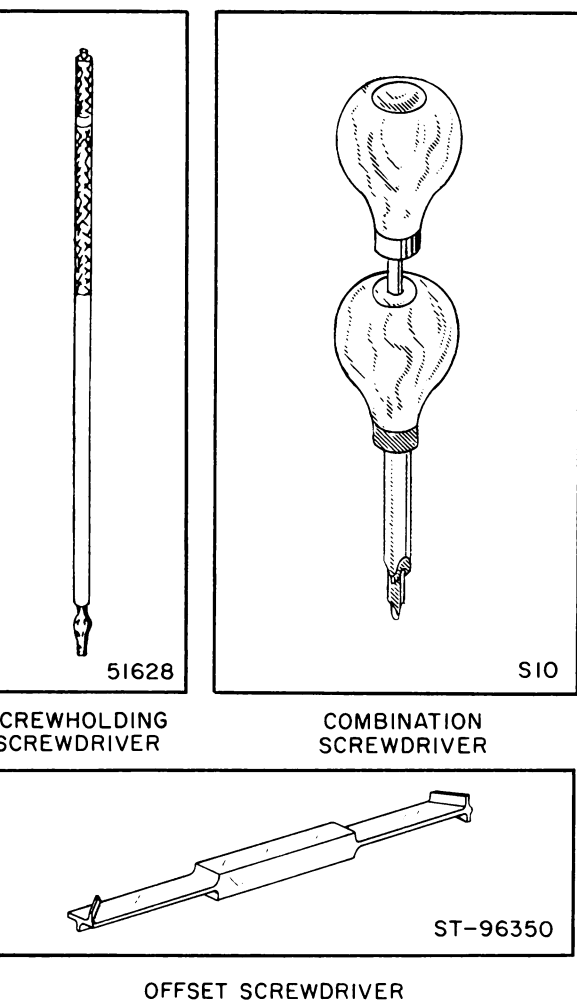
To prevent slippage when using, keep the blades of screwdrivers clean and dry. Use an approved solvent to remove excess grease. Wipe with a clean cloth. When not in use, keep screwdrivers where the blades are protected, pre-

ferably in a separate location or holder. It is not a good idea to throw them into a drawer or box with other tools.

Typewriter Pliers

Pliers used for typewriter servicing may include ordinary wire pliers; duck-billed pliers; long, round-nose pliers; long, needle-nose pliers; parallel, flat-nose pliers; and many other types. Pliers with forming jaws are used primarily for forming key levers; they can be used on all makes of typewriters. Three-prong pliers with one set of jaws are also very useful for making adjustments on all makes of typewriters. Peen pliers are good for raising and lowering key levers. Aligning pliers are used for getting type into position, and other pliers are used for special purposes.

UNDERWOOD PLIERS.—Figure 14-4 shows some different types of pliers (with manufacturer's part numbers in parentheses) used in the repair and maintenance of Underwood standard typewriters. A typesoldering gage is also illustrated. The peening pliers shown are u-



1.14(61)B

Figure 14-2.—Special types of screwdrivers.

For bending type bars and other parts of the machine. The key top detaching pliers are used for taking key tops off, and the key top attaching pliers are used for putting tops back on. Three-jaw pliers are excellent for adjusting different parts of a typewriter. The nippers shown have interchangeable jaws and can be used for cutting and peening.

REMINGTON RAND PLIERS.—Study the pliers illustrated in figure 14-5. The needle-nose pliers are good for getting into cramped places on a typewriter. Rolling pliers can be used for bending key levers and similar items. Tailing pliers are useful for shaping certain parts of a typewriter.

ROYAL MCBEE PLIERS.—Two special pliers used on Royal McBee typewriters are illustrated in figure 14-6. The names of the pliers indicate the purpose for which they are used.

Typewriter Wrenches

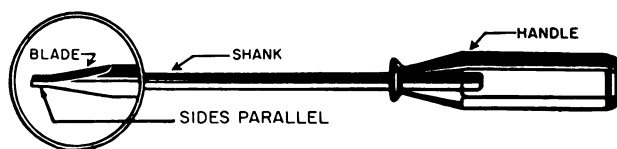
You need many different kinds of wrenches for repairing typewriters. They must have the size, shape, and opening necessary to fit all types of nuts on a typewriter. Special wrenches are required for certain makes and models of typewriters. Figure 14-7 shows a group of typewriter wrenches which are good for general purpose work. An open-end flat wrench, for example, fits many parts on all makes of typewriters.

ROYAL MCBEE WRENCHES AND TOOLS.—Some Royal McBee typewriter tools are shown in figure 14-8. The segment pick is used for cleaning foreign matter from the segment.

UNDERWOOD WRENCHES AND SPECIAL TOOLS.—Wrenches and tools illustrated in figure 14-9 are used for repairing Underwood standard typewriters. Names of the wrenches and tools indicate the purpose for which they are used. T-benders are made in various sizes and are used for forming different parts of a typewriter, such as a key lever, universal bar and lift rail, type bar, actuating lever bracket, bichrome bracket, and a cylinder scale.

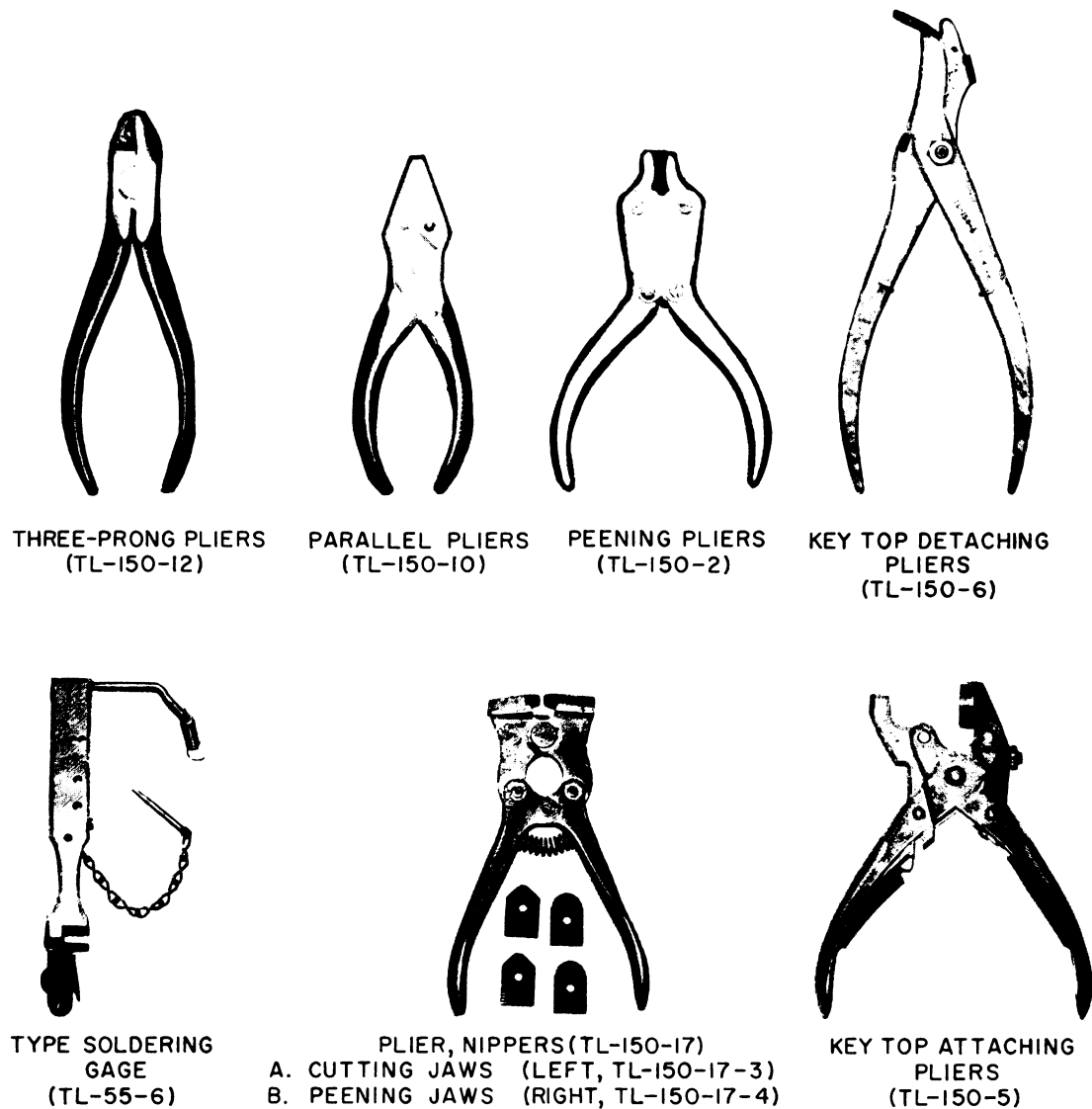
Spring hooks are essential for removing and fastening springs. A scribe is used for marking or writing on metal. Allen wrenches are hexagonal in shape and are used for removing nuts with countersunk heads of this shape.

REMINGTON WRENCHES AND SPECIAL TOOLS.—Some Remington Rand wrenches and special tools are shown in figure 14-10. The



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Figure 14-3.—Correctly ground screwdriver blade.



1.21(61)A

Figure 14-4.—Underwood typewriter pliers and type of soldering gage.

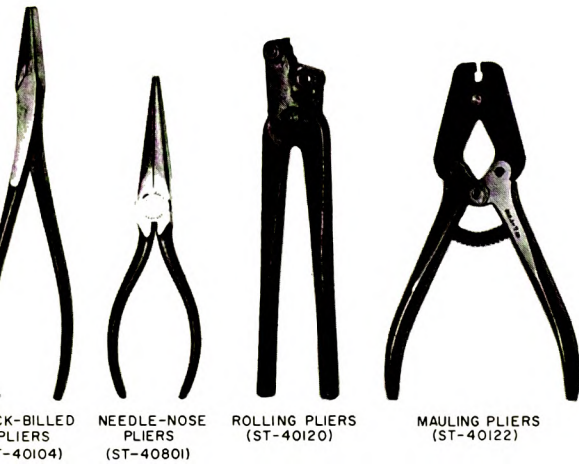
atomizer is used for spraying oil on moving parts of a typewriter. The fulcrum wire is used for holding type bars after they have been removed from the segment. Note the shapes and sizes of the special wrenches.

SOLDERING

Soldering is used to join iron, nickel, lead, tin, copper, zinc, aluminum, and many alloys. Soldering is a simple, fast, and effective joining

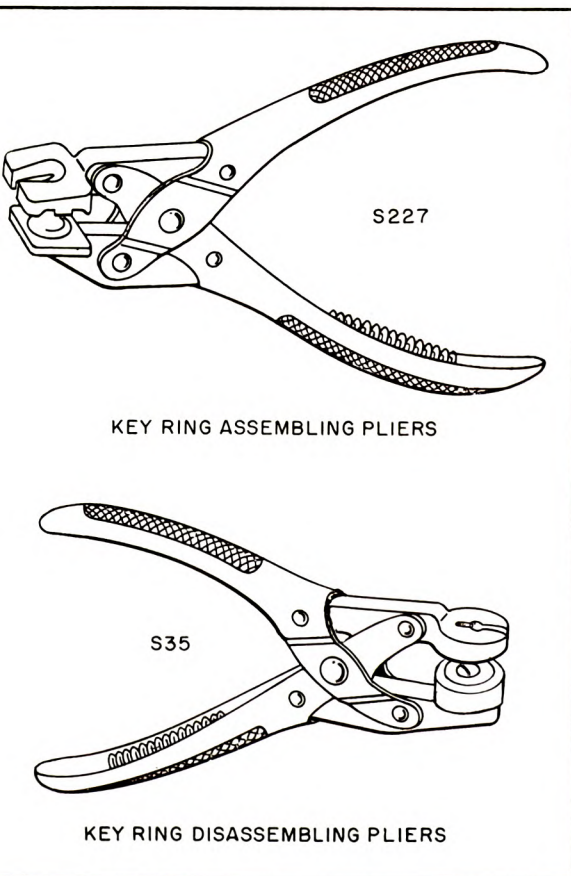
process; it is particularly useful for electrical connections, type soldering, and repairs to various metals. Soldered joints are not as strong as welded joints, and so are not used where any great mechanical strength is required.

In order to advance in rate, you are required to soft-solder metals, using Prestolite or an alcohol torch or electric soldering copper. Information pertaining to the tools and skills required to join metals with soft solder is given in the paragraphs which follow. Additional



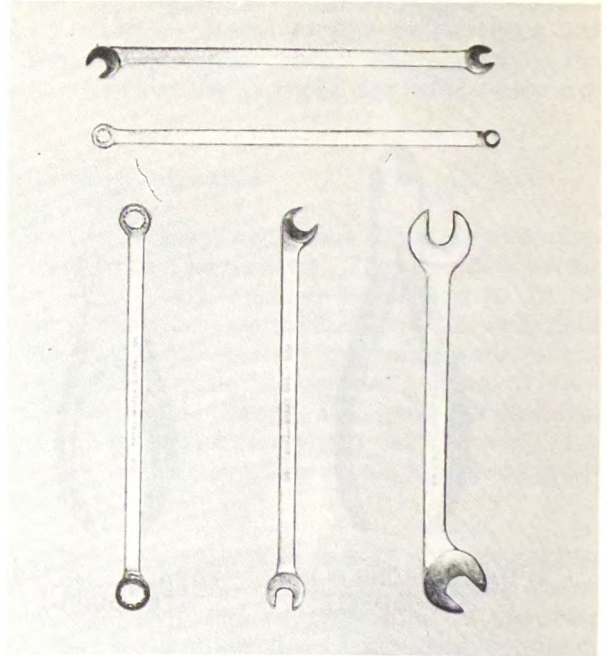
1.21(61)

Figure 14-5.—Remington Rand type-writer pliers.



1.21(61)C

Figure 14-6.—Royal-McBee typewriter pliers.



1.16(61)A

Figure 14-7.—General purpose type-writer wrenches.

information concerning soldering equipment, as well as techniques, can be obtained from either Basic Handtools, NavPers 10085-A or Shipfitter 3 & 2, NavPers 10595-B.

SOLDERING EQUIPMENT

Soldering requires relatively little equipment. For most soldering jobs, you will need only a source of heat, soldering coppers, solder, and a flux.

(Note: Instrumentmen generally use only a soldering gun, pistol type, alcohol torches, propane torch kits and flux. This equipment is generally secured through normal supply channels.)

Sources Of Heat

The sources of heat used for soldering vary according to the method used and the equipment that is available. Welding torches, blowtorches, forges, gas ovens or furnaces, and other heating devices may be used. Most commonly, the heating devices are used to heat soldering coppers which then supply the heat required to heat the surfaces and thus melt the solder. However,

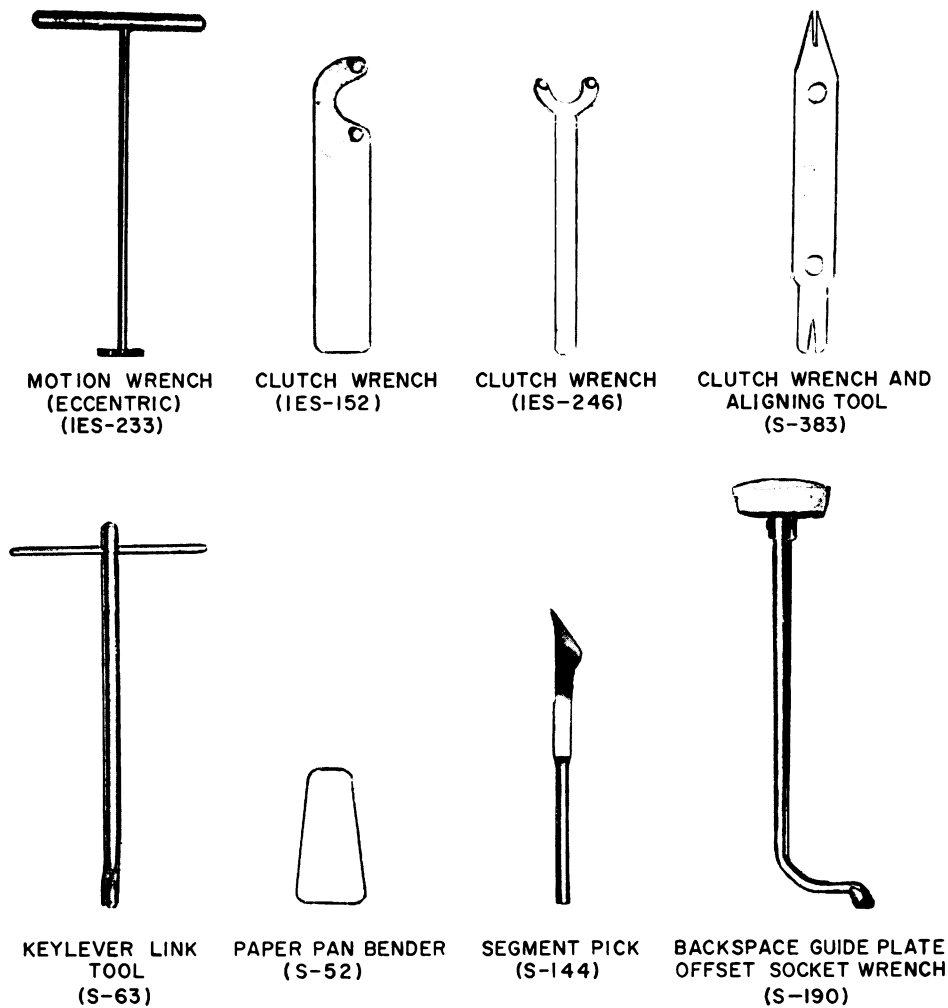


Figure 14-8.—Royal-McBee wrenches and tools.

1.16(61)B

the heating devices are sometimes used for the direct heating of the surfaces to be joined; in this case, the solder is melted by the heat from the heated surfaces.

In order to advance in rate you are required to soft-solder metals, using Prestolite or alcohol torch or electric soldering copper. Therefore, other methods will not be discussed in this section.

An alcohol torch is shown in figure 14-11. This torch is a self-contained unit which requires no outside source of pressure. The alcohol tank is filled about two-thirds full of alcohol and then sealed. To operate the torch, remove the cap and light the wick. The flame from the

wick heats the jet tube, causing the liquid alcohol in the container to vaporize and expand. The expansion of the alcohol forces the alcohol vapor from the jet opening, where it burns with a hot flame.

Soldering Coppers and Guns

Electric soldering coppers, sometimes called a soldering iron (fig. 14-12), are built with internal heating coils. The heads are removable and interchangeable.

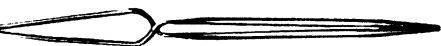
An a-c, d-c soldering iron without thermostatic control is illustrated in part A of figure 14-13. This is a standard type soldering iron,



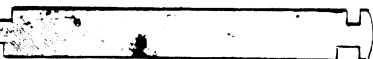
**TWISTER (T-BENDER),
(TL-230-4)**



**TYPE ALIGNING WRENCH,
(TL-250-1)**



**TWEEZERS,
(TL-225-1)**



**BACK SPACER WRENCH,
(TL-250-1-2)**



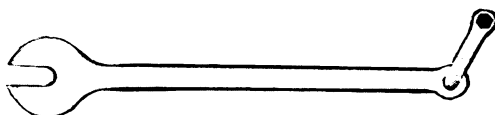
**SOCKET WRENCH,
(TL-250-7-1)**



**CENTERING PUNCH,
(TL-160-1)**



**TYPE DRIFT PUNCH,
(TL-16-4)**



**FRICTION TOGGLE JOINT WRENCH,
(TL-250-10-1)**



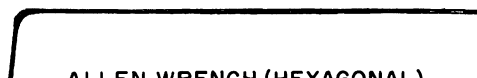
**ESCAPEMENT TRIP WRENCH,
(TL-250-3-2)**



**S-WRENCH (MOTION),
(TL-250-3-21)**



**S-WRENCH (SMALL, ON-FEET),
(TL-250-3-17)**



**ALLEN WRENCH (HEXAGONAL),
(TL-250-13-1)**



**SCRIBER,
(TL-175-1)**



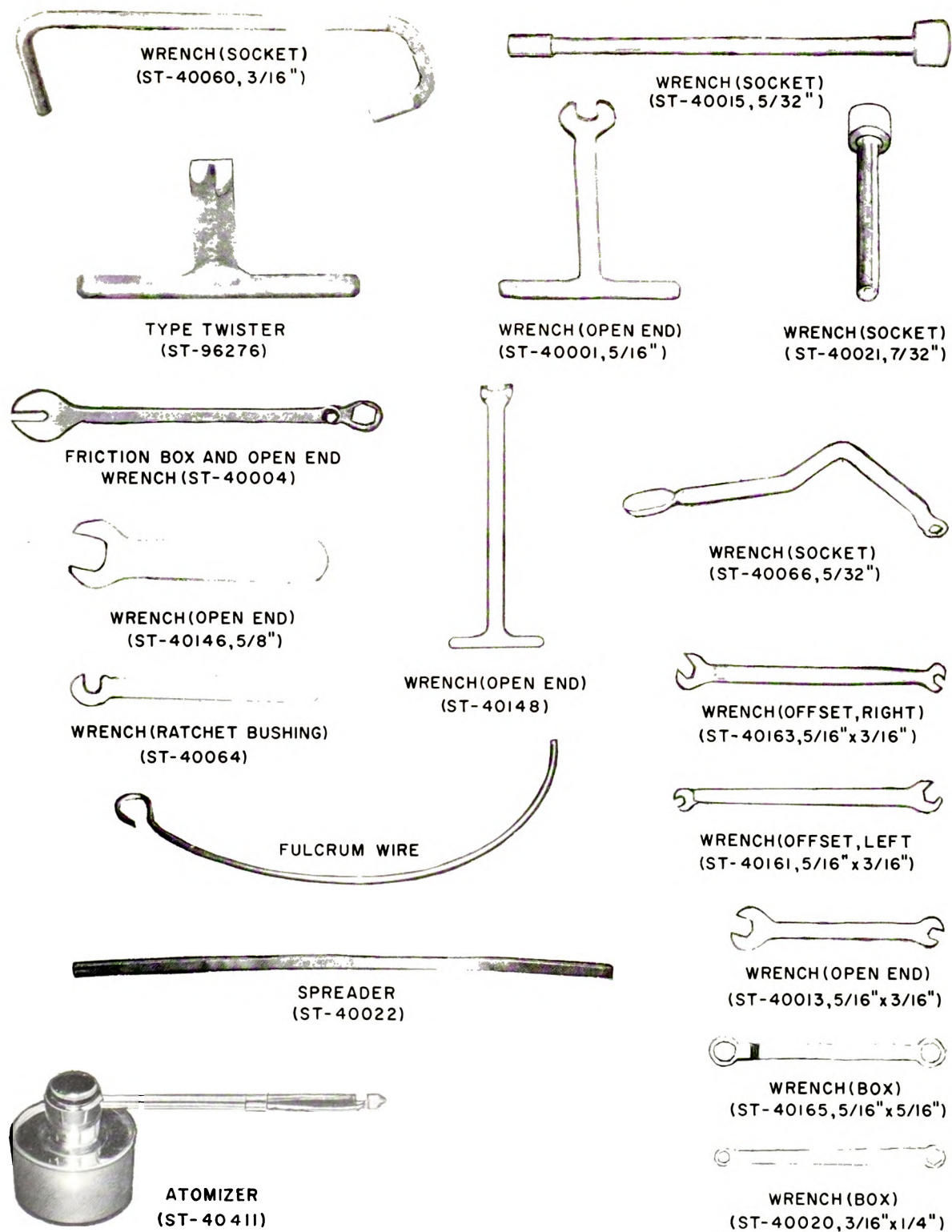
**SPRING HOOK (SMALL),
(TL-90-2)**



**SPRING HOOK (LARGE),
(TL-90-1)**

Figure 14-9.—Underwood wrenches and special tools.

1.16(61)C



1.16(61)D

Figure 14-10.—Remington Rand wrenches and special tools.

complete with copper tip and a six-foot cord. It operates on 110 volts a-c or d-c. The iron is available with a pyramidal or chisel-shaped tip and at various wattage ratings.

Part B of figure 14-13 shows an electric soldering-iron set equipped with a built-in thermostat, set to maintain the heating element temperature between 700° and 775° F. The set includes a handle, a full set of tips, and a resting stand. The tips are shown in part C of figure 14-13.

The soldering gun, shown in figure 14-14, is extremely handy for light work. A soldering gun is a light-duty, fast heating unit with a built-in automatic spotlight. The tips are replaceable. The two-position switch (connected to the trigger) affords dual heat; the first position is 100 watts and the second position is 135 watts. The gun contains a transformer; its use is restricted to 115-volt 60-cycle operation only. It is NOT to be used on d-c.

The tip of the soldering gun is in the form of a narrow loop and makes a closed circuit with the secondary winding of the transformer. The flow of current through the tip heats it to soldering temperature in a matter of seconds. The gun is turned ON and OFF for each soldering operation.

The cross sectional area of the secondary winding is considerably larger than that of the soldering tip, and this tends to decrease the heating in the transformer and to concentrate it in the point where it is needed.

Continuous use of the soldering gun will overload the transformer and create the danger of a burn-out. Therefore, the trigger must not be held in the heating position continuously for long periods of time. Release it as soon as the soldering operation is over.

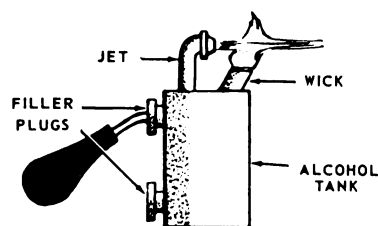


Figure 14-11.—Alcohol torch.

11.143



1.26A

Figure 14-12.—Full view of an electric soldering copper.

CLEANING SOLDERING COPPERS

Soldering coppers should be cleaned just before they are used. Sal ammoniac is usually used for this purpose. The copper may be rubbed on a cake of sal ammoniac or dipped into a container of powdered sal ammoniac; it must then be wiped clean with a cloth, so that all grains of sal ammoniac are removed. Another way to clean coppers is to dip them in a solution made by dissolving a small amount of sal ammoniac in water.

SOLDERS

Most soft solders are alloys of tin and lead. Occasionally antimony, silver, arsenic, or bismuth are added to give special properties to the solders. Solders used for joining aluminum are usually alloys of tin and zinc or of tin and cadmium. Soft solders have melting points below 800° F and below the melting points of the metals being joined. The melting points of most tin-lead solders range from about 360° F to about 465° F.

Tin-lead solders are usually identified by numbers which indicate the percentage of tin and the percentage of lead. The first number gives the percentage of tin, the second gives the percentage of lead. For example, a 30/70 solder is an alloy of 30 percent tin and 70 percent lead. A 50/50 solder (sometimes called half-and-half solder) is an alloy of 50 percent tin and 50 percent lead. A 15/85 solder is an alloy of 15 percent tin and 85 percent lead. Solders containing a high percentage of tin are more expensive than those containing a high percentage of lead. In general, the solders which contain a high percentage of tin have lower melting points than those which contain a high percentage of lead.

Solders are available in various forms, including bars, wires, ingots, and powders. Wire solder is available with or without a flux core.

SILVER BRAZING

As an IM3 striker, you must be able to braze brass and steel. Silver brazing is a brazing process wherein coalescence (joining of metals) is produced by heating with a gas flame and by using a silver alloy filler metal having a melting point above 800° F, but below the melting point of the base metal. The filler metal is distributed in the joint by capillary attraction.

Since capillary attraction is important in the silver brazing process, it will be helpful to understand what is meant by this term. Perhaps the best way to understand capillary attraction is to consider some everyday examples of the process. If you put one end of a strip of cloth in a glass of water and allow the other end to hang over the edge of the glass, the end of the cloth which is not in the water will become wet. Water rises in the cloth by capillary attraction. When you use a blotter, the ink is drawn up into the blotter by capillary attraction. The wick on an oil lamp can be lit because the oil rises in the wick by capillary attraction. In each of these examples, we have a LIQUID (water, ink, oil) which moves into an opening in a SOLID (cloth, blotter, wick) by the process called capillary attraction. A basic rule

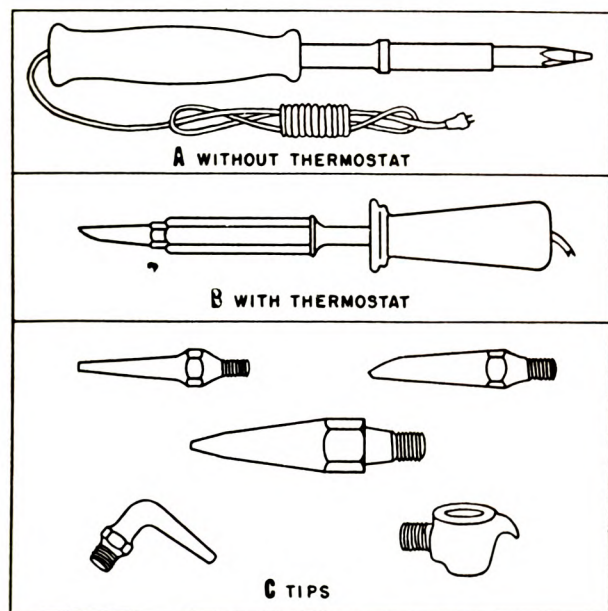
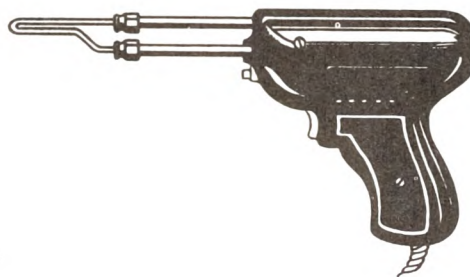


Figure 14-13.—Electric soldering irons and components.



1.27

Figure 14-14.—Soldering gun.

of capillary attraction is that the distance the liquid will be drawn into the opening in the solid depends on the size of the opening in the solid; the smaller the opening, the farther the liquid will be drawn in.

In just the same way, capillary attraction causes the melted filler metal used in silver brazing to be drawn into the narrow clearance between the joining members. Capillary attraction will not work unless the filler metal is MELTED and unless the size of the opening is quite small. Therefore, the application of heat and the use of a very small clearance between joining members are essential to the silver brazing process. The heat is necessary in order to melt the filler metal and to keep it molten; the small clearance is necessary to allow capillary attraction to draw the molten metal into the space between the joint members.

Except for the higher melting temperature, brazing is about the same as soft soldering. It is also called SILVER SOLDERING or HARD SOLDERING. A brazed joint is much stronger than a soft-soldered joint.

TORCHES

Successful silver brazing depends largely upon the operator's ability to control the application of heat by manipulating the torch. A lightweight torch with a flexible extension tube (fig. 14-15) simplifies the silver brazing procedure and helps reduce operator fatigue. The flexible extension tube is made of soft copper, and can be bent as desired to heat the surfaces to be joined. Lightweight torches are easy to handle and simplify the problem of applying the flame to that portion of the joint requiring heat at a given instant.

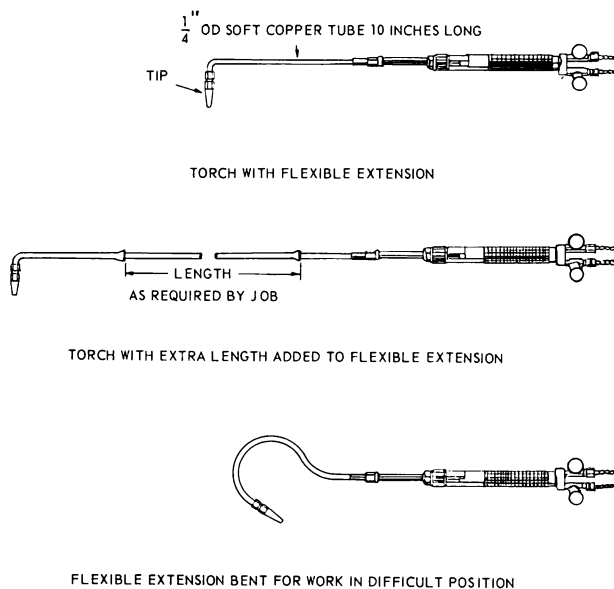
Torches are provided with various sizes of tips, since one tip size cannot be used for making joints on all thicknesses of metal. Tips are designed to beat a large area and still allow little or no "bounce" (reflected heat).

SILVER BRAZING FILLER METALS

Silver brazing filler metals are nonferrous metals or alloys which have a melting temperature above 800° F but below the melting point of the base metal being joined. You may have heard these silver brazing filler metals referred to as silver solder, hard solder, or brazing alloys, but the correct term is SILVER BRAZING FILLER METAL. The American Welding Society defines a brazing filler metal as a metal or alloy to be added in making a braze.

Silver brazing filler metals covered in Navy Specifications possess certain characteristics. Some of the major characteristics are:

1. They have a low melting point.
2. They have high tensile strength.
3. They are highly resistant to corrosion.
4. They flow readily at the lower brazing temperatures.
5. They braze readily to copper and to copper alloys.



11.114

Figure 14-15.—Lightweight oxyacetylene torches with flexible extension tubes.

There are a number of different silver brazing filler metals available. The metals commonly used for silver brazing filler metals include silver, copper, zinc, phosphorus, cadmium, and nickel. The percentage of the various metals included in any brazing filler metal determines the color of the alloy, its strength, melting point, and flow point.

FLUXES

All silver brazing operations require the use of a flux. The flux acts to prevent the oxidation of the metal surfaces and to remove oxides already present. Flux also increases the flow of the brazing filler metal and increases its ability to adhere to the base metal. It brings the brazing filler metal into immediate contact with the metals being joined, and permits the filler to penetrate the pores of the metal, thus forming a strong joint.

The fluxes used in the Navy are selected in accordance with specifications, so as to meet the requirements of brazing with silver-base alloys. For best results, a flux must become active at a temperature slightly below the melting point of the filler metal, and must remain fluid at the brazing temperature. Regardless of the type of flux you select, it is most important that you apply it in such a manner that all oxide film is removed.

Flux may be obtained in three forms: liquid, paste, and powder. When used either in paste form or in liquid form, the flux is applied with a brush to both parts of the joint; best results are obtained when the filler metal also is given a coat. Use a circular motion in brushing it on, and let the flux extend outside the joint or fitting. Brushing the flux on with a circular motion gives a uniform coating and lessens the possibility of bare spots that will oxidize during heating. Fluxing the filler metal can be accomplished by heating the filler rod and dipping it into the flux. Sufficient flux to do the job will stick to the hot rod.

Borax or a mixture of borax and other chemicals is most often used as a flux. Up to a certain point, heat causes borax to swell and bubble. Common crystalline borax, although it appears perfectly dry, contains approximately 47 percent water of crystallization (water which is chemically combined in a crystallized substance). When the borax is heated, this water is driven off, causing the borax to appear to boil. Borax may be mixed with water to form a

paste, but because of the ability of borax to hold water, it will quickly take up the water and become crystalline borax again. If commercial powdered borax is used, see that it is kept in sealed glass jars.

If a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid may be used as a flux for brazing.

When applying flux or assembling the parts, avoid handling the polished parts of the joint or you will defeat the purpose of cleaning. If the coating of flux dries before the parts are assembled, a fresh coating of flux should be applied. Flux should always be applied as soon as a joint area is cleaned even though it will not be brazed immediately. After the brazing is completed, wash with warm water to clean away all the residue left by the flux.

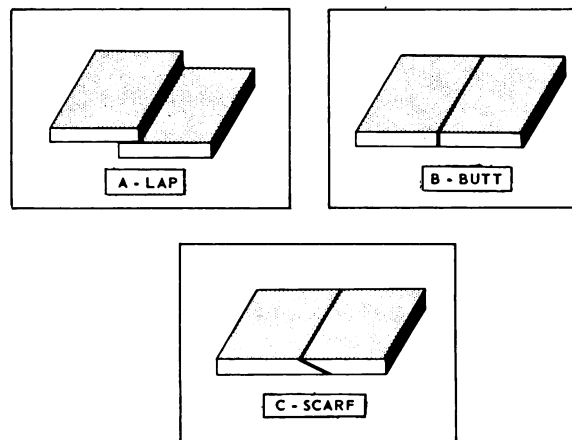
TYPES OF JOINTS

Since the filler metal used in silver brazing must be distributed by capillary action, the joints must be of a type that requires closeness of fit. In silver brazing there are three basic joint designs (fig. 14-16); lap, butt, and scarf. The joint members in which these designs are used may be flat, round, tubular or irregular in cross section.

The lap joint design is used most frequently in silver brazing, especially in pipe work. Good practice requires a length of lap at least three times the thickness of the metal being joined. A 0.001-inch to 0.003-inch clearance between the members of the joint provides the greatest strength with silver-base brazing filler metals.

High strength butt joints can be made if a joint clearance between 0.001 and 0.003 inch can be maintained in the finished braze. The edges of the joint must be perfectly square so that a uniform clearance exists between all portions of the joint surfaces. Butt joints are usually used where the double thickness of a lap joint is undesirable. When double metal thickness is objectionable, the scarf joint is probably better.

A scarf joint provides an increased area of bond without increasing the thickness of the joint. The area of bond, however, depends on the angle at which the edges of the joint are scarfed. Usually, an area of bond two to three times that of a butt joint in the same thickness of material is desirable. A scarf angle of 30° gives a bond area twice that of a 90° butt joint and a scarf angle of $19\frac{1}{2}^\circ$ gives a bond area three times that of a butt joint.



11.
Figure 14-16.—Joint designs for silver brazing.

Many modifications of these basic joint signs are employed. In some instances, silver brazing filler metal is added when proper temperature has been attained. In other instances, the filler metal is preplaced in the joint before heat is applied. This technique is common in pipe work where special fittings containing pre-inserted rings of silver brazing filler metal are employed. The technique is also used in sheet metal work involving locked seams. Here the silver brazing filler metal is placed in the seam before it is locked. The preplaced insert method produces a strong, leak-tight joint in both sheet metal and pipe work.

SILVER BRAZING TECHNIQUES

Some knowledge of the principles of heat flow through metals is necessary for an understanding of silver brazing techniques. The following points are particularly important:

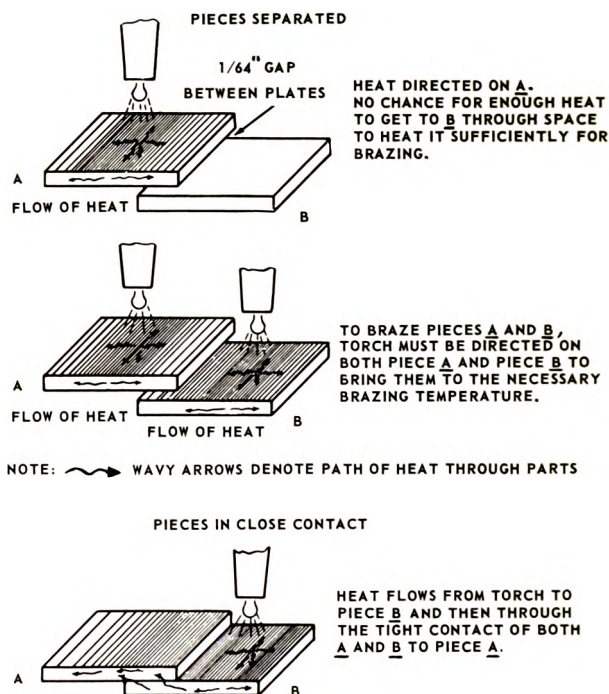
1. Heat always flows from a hotter area to a colder area.
2. The process by which heat flows from one molecule to molecule through a metal (fig. 14-17) is called CONDUCTION. Conduction takes place quite rapidly in most metals, but air is a very poor conductor of heat. Therefore, if two pieces of metal that are to be joined by silver brazing are not in contact with each other, each piece must be heated separately. If the two pieces are in contact with each other, you can heat them both by applying heat to one of the pieces; the second piece will be heated by conduction.

the first piece. These principles are illustrated in figure 14-18.

In the molten state, filler metal flows to the colder towards the hotter areas on a cold surface. Thus, you might say that the filler metal flows in a direction OPPOSITE the direction of flow of the heat. This principle is illustrated in figure 14-19.

The filler metal and the flux used in brazing cannot occupy the same space at the same time. Therefore, a clearance must be provided in the setup of the joint so that the filler metal can flow in and the flux can flow out. Heat should be applied in the manner shown in figure 14-20 so that the flux will flow out and the filler metal reaches the bonding temperature.

Heat travels faster through some metals than through others (fig. 14-21). Although all metals and alloys have high conductivity as compared with most other substances, there is a good deal of variation in the speed with which various metals and alloys will conduct heat. Silver, for example, is a very rapid conductor of heat. When two pieces of different metals are to be joined by silver brazing, the difference in heat conductivity of the two metals causes some problems in heating. For example, if you are trying to join a steel part and a copper part by silver brazing, you will find that the steel part reaches the joining temperature more rapidly and has a tendency to overheat because the heat is carried away from it more slowly. The copper part, on the other hand, conducts heat away from the brazing area more



11.118

Figure 14-18.—Flow of heat.

rapidly than the steel part does. Therefore, more heat is required to bring the copper part to the brazing temperature.

As you can see, control of heat is one of the most difficult parts of silver brazing. In order to control heat properly, you must learn to manipulate the torch correctly and you must remember the points just discussed concerning the flow of heat through metals. Basically, the problem of heat control in silver brazing is one of bringing BOTH parts to the correct temperature at the same time. If one piece is hot enough but the other is not, the filler metal will flow onto the hot piece but it will not bond to the cooler piece.

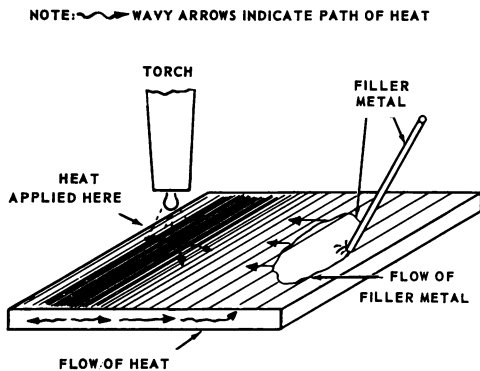
Clean and properly fitted joints are necessary for satisfactory silver brazing. All parts to be brazed must be thoroughly cleaned to remove surface scale, oxide, oil, and grease. Sanding, grinding, sandblasting, wire brushing, and filing are effective for removing rust and corrosion. Oil and grease should be removed with solutions of trichloroethylene or trisodium phosphate, not heat. Never attempt to braze dirty metal.



11.117

Figure 14-17.—Conduction of heat in a metal.

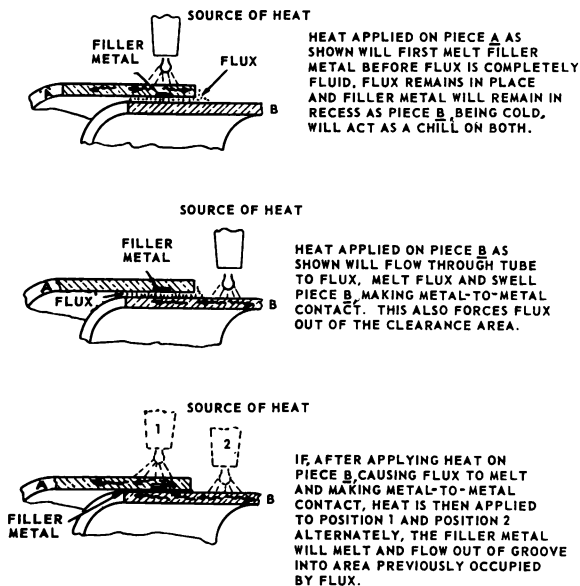
When applying heat with the oxyacetylene torch for brazing with a silver-base filler metal, use a carburizing flame. Select a torch tip to suit the type of work you are doing. (Ordinarily a size 4, 5, or 6 tip is suitable for silver brazing sheet stock.) Keep the inner cone of the flame from 1/4 to 1/2 inch away from the metal. Play the flame over the surface with a circular, sweeping motion, so that you obtain uniform heating of the parts to be joined. The flame should be soft so that it will not blow or boil the molten filler metal.



11.119

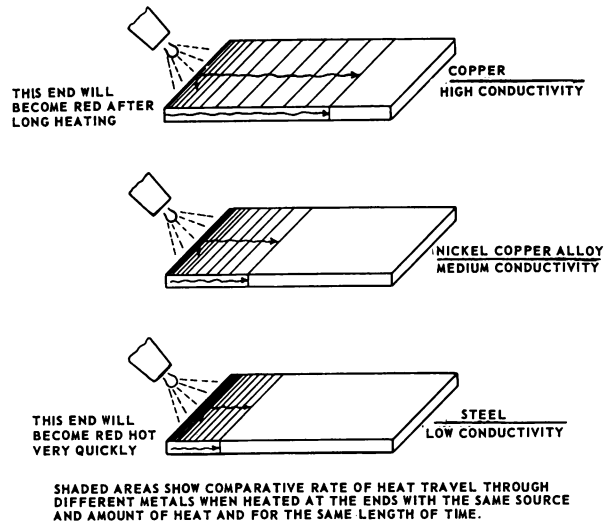
Figure 14-19.—Flow of molten filler metal.

NOTE: ~~~~~ WAVY ARROWS INDICATE PATH OF HEAT THROUGH CYLINDRICAL PARTS



11.120

Figure 14-20.—Flow of flux and filler metal.



11.121

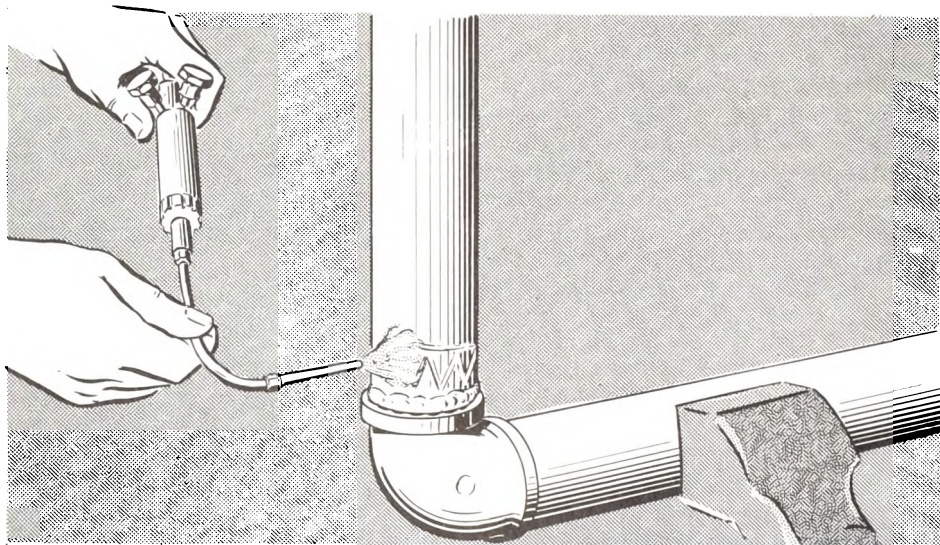
Figure 14-21.—Relative rate of heat flow through copper, nickel-copper alloy, and steel.

Bring up the temperature of the parts until the flux on them is melted. Continue heating the parts to be joined until they are hot enough to melt the filler rod. The filler should be melted by the heat of the joint, not by the flame. It should flow like water wherever the flux has been applied. Avoid overheating. Use just enough heat to get the parts of the joint hot enough to melt the filler metal so that it can flow.

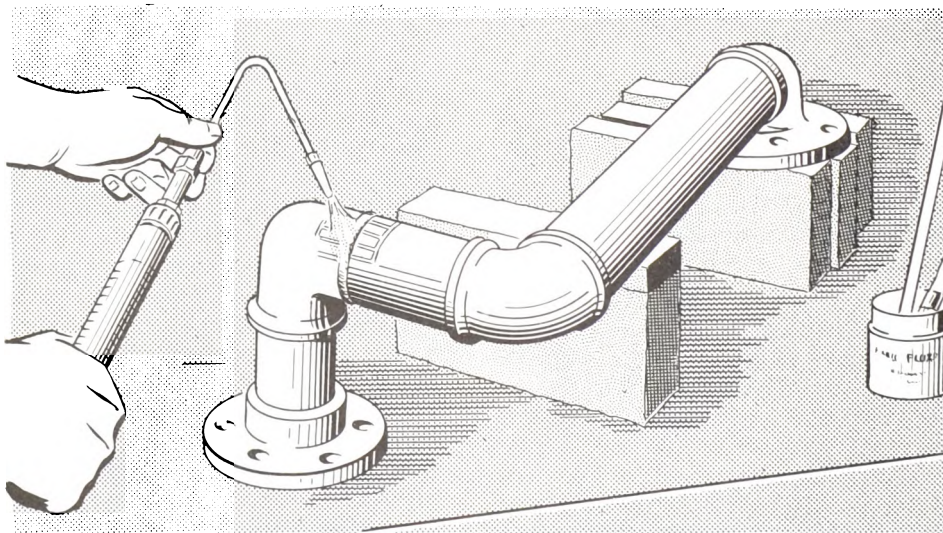
Two methods are used to make joints with silver-base brazing filler metal: the INSERT METHOD, and the FEED-IN METHOD. With either method, the parts must be adequately supported during heating. It is also important that the work be held firmly in position until silver brazing filler metal has completely solidified.

When using the INSERT METHOD, a strip of the silver-base filler metal is inserted in the joint prior to assembly. Before brazing the parts, clean them with emery cloth, sandpaper, or some other abrasive and apply flux with a brush. Next, fit the two parts together and align them. Then light off the torch and direct the heat on the tube or thinner portion as shown in figure 14-22. The lines drawn on the tube indicate the path of the torch while heating the tube.

Heat applied to the tubing causes it to swell and bring the surface of the tube into contact



A



B

Figure 14-22.—Applying heat for silver brazing a tube and fitting.

11.122

with the inside surface of the fitting. This closes the clearance area, forcing the flux from either end of the joint. Be sure to heat the entire circumference of the tube until flux begins to flow. Flux flow tells you that the tube has expanded sufficiently and is the signal to proceed to the second phase of heating. As soon as the flux flows freely—about 6 seconds after fluidity

becomes apparent—direct the flame to that portion of the fitting hub farthest from the junction of the tube and the fitting. Rotate the flame over the joint segment until brazing filler metal appears at the junction of the pipe and fitting. At that moment, flick the torch away so that the flame wipes toward the pipe. This completes one segment of the joint. The procedure is

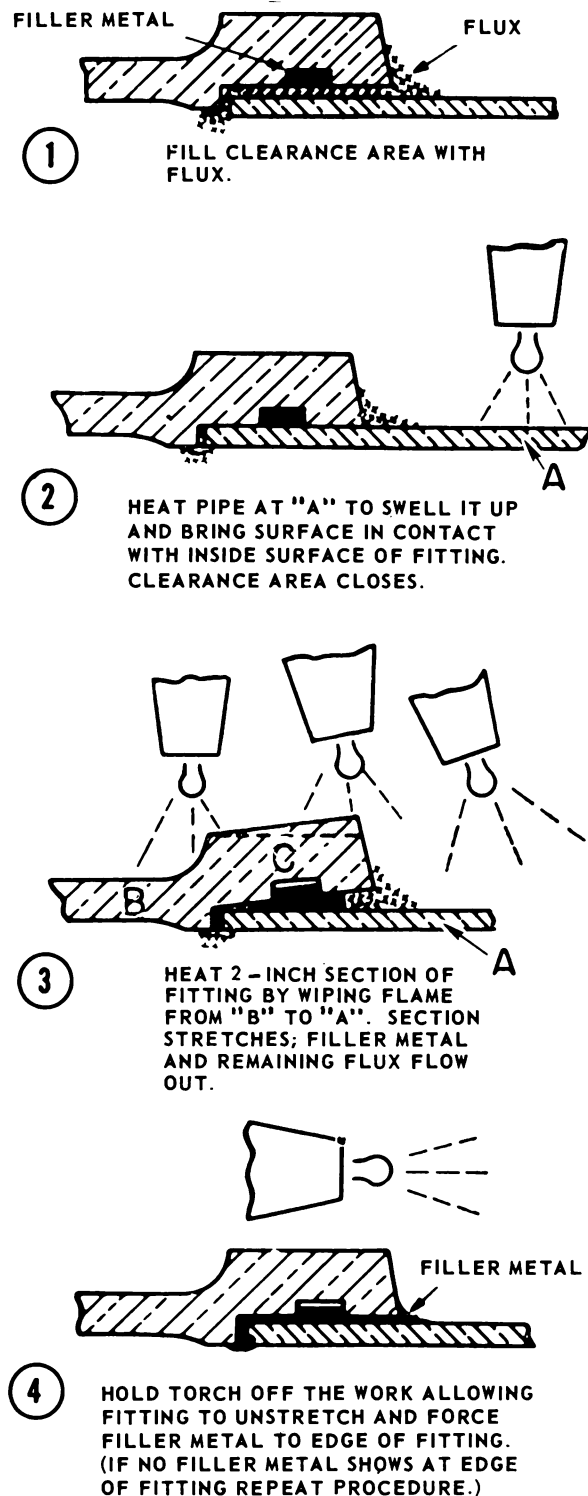
repeated until all segments are completed. A satisfactory joint shows a continuous ring of filler metal at the end of the fitting. The ring must be smooth and concave.

In the insert method the filler metal will not leave the recess unless both parts are at the proper bonding temperature. If one of the parts is up to temperature and the other is not, the filler metal will not flow because it will be cooled or quenched by the surface not yet up to temperature. By playing the torch over a 2-inch or 3-inch section of the fitting you can cause the fitting to stretch or open up and let whatever remaining flux is present run out. Then hold the torch off the work and the fitting will return to normal size and force the filler metal to the edge of the fitting. You may be sure that a good joint is formed when you can see the filler metal at one or both edges of the joined area. Figure 14-23 shows the step by step process of brazing by the insert method.

The FEED-IN METHOD, sometimes called the STICK-FEED METHOD, is accomplished by feeding the filler metal by hand into the area to be joined. In this method, remember that the filler metal always flows along a heated surface from the cooler to the hotter section. In other words, the filler metal flows toward the source of heat or to the point where the heat is being applied. In this method, feed the filler metal to the outer edge of the joint while directing heat to the inner edge of the joint. Figure 14-24 illustrates the step-by-step technique for brazing a joint by the feed-in method.

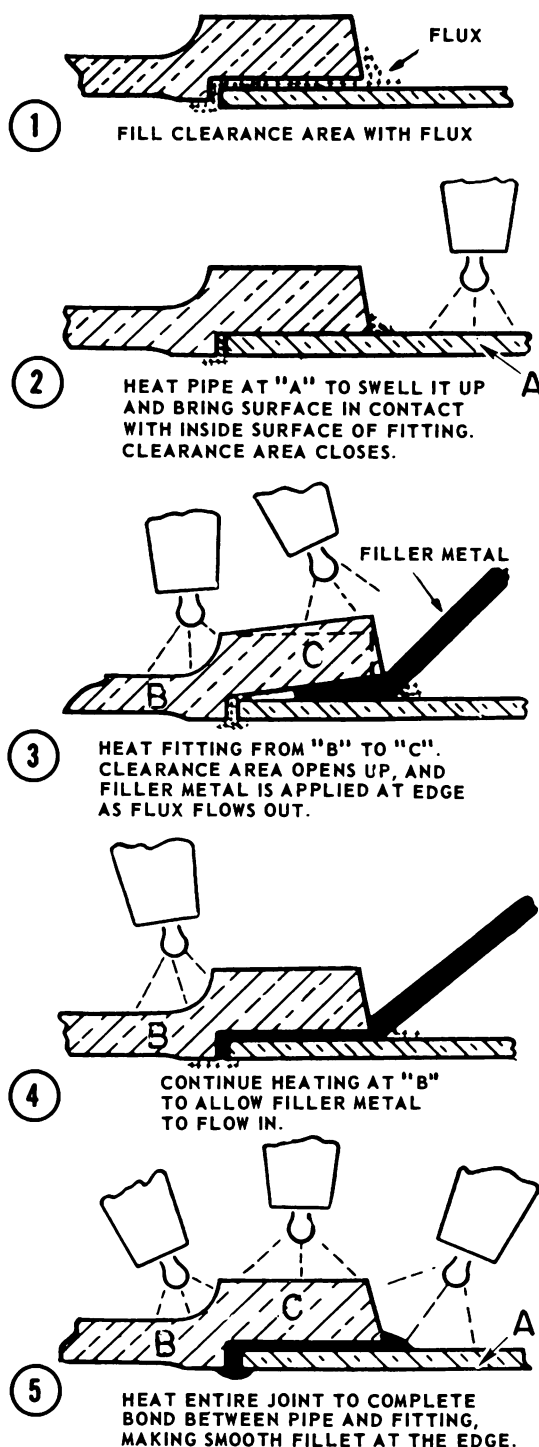
The parts to be joined are cleaned and fluxed in the same manner as in the insert method. When the parts are fitted together the clearance area is filled with flux. After aligning the parts, apply heat as previously described.

Heat is then applied to the fitting or the inner edge of the joint at the same time that the filler metal is fed at the outer edge of the joint. As the filler metal will flow toward the hottest section, it will flow through the joint toward the point at which the heat is being applied. In this method, it is left entirely to the judgment of the individual performing the job to determine when both parts are properly heated and when to feed the filler metal. It is also left to his judgment to determine when sufficient filler metal has been fed into the joint to completely fill the space between the two parts being joined. Skillful torch manipulation is necessary to apply heat to the proper



11.123

Figure 14-23.—Insert method of silver brazing.



11.124
Figure 14-24.—Feed-in method of silver brazing.

point to cause the filler metal to flow from the cooler to the hotter section. In the feed-in method, filler metal visible at the edge of the joint does not necessarily indicate that the entire joint is filled.

The difference, then, between making a joint by the insert method and with the feed-in method is in procedure. When using the insert method, you heat a section and remove the torch with a wiping motion which causes the filler metal to flow from the insert. In the feed-in method, after you heat a section, the flame must be directed to the inside edge of the joint while the filler metal is being fed in at the outside edge of the fitting.

After the joint has been completed and cooled, clean the joint area with a wire brush and warm water. This will remove flux, scale, and discoloration.

The description of the brazing techniques in the preceding paragraphs apply specifically to joints between tubes and fittings in piping systems. Except for minor differences, the procedure is the same when brazing sheet, strap, or bar stock. Here, though, the feed-in method rather than the insert method is usually employed.

Additional information concerning pipe brazing and seam brazing can be obtained from either manufacturers' technical manuals or rate training manuals such as Shipfitter 3 & 2. NavPers 10595-B.

HEAT TREATING

Heat treatment may be defined as an operation or combination of operations that involves the heating and cooling of a solid metal or alloy in order to obtain certain desirable properties or conditions. The basic purpose of all heat treatment is to change the properties of the metal in some particular way. The change may be required in order to improve the metal for its intended service, to facilitate the accomplishment of some subsequent operation such as machining, or to relieve stresses in the material. Heat treatment is commonly used to develop or change such properties as hardness, ductility, toughness, machinability, wear resistance, brittleness, magnetism, and electrical conductivity.

No single heat treating operation could be used to produce all of these changes. In fact, improving a metal in one way may change it undesirably in some other way. For example,

hardening and tempering of carbon steel will increase the tensile strength and yield strength; at the same time, however, it may reduce the ductility, as measured by percent of elongation. Therefore, heat treating will not be successful unless you know exactly what properties you can afford to sacrifice, and exactly how to produce the required properties in the particular metal with which you are working.

In order to qualify for advancement to IM3, you must be able to anneal, harden, and temper gravers, springs and screwdriver bits. Therefore, the sections which follow cover the forms of heat treatment, commonly used for ferrous metals, that you will probably be concerned with as an Instrumentman. (NOTE: Annealing is also used for nonferrous metals.) If you desire to obtain a more extensive knowledge of the theory of heat treating and other forms of heat treatment (normalizing and case-hardening), consult the Metals Handbook, published by the American Society for Metals, or any textbook on physical metallurgy.

ANNEALING

The chief purposes of annealing are: (1) to relieve internal strains, and (2) to make a metal soft enough for machining. The process is accomplished by heating the metal to a high temperature, holding it at this temperature until the grain structure has been refined, and then allowing it to cool slowly. Both the temperature of the operation and the rate of cooling depend upon the metal being treated, and the purpose for which it is to be used.

Besides rendering metal more workable, annealing can also be used to alter other physical properties, such as magnetism and electrical conductivity. Annealing is often used for softening nonferrous alloys and pure metals after they have been hardened by cold work. Some of these alloys require annealing operations which are different from those for steel. For example, duralumin is heated to 986° F, and then cooled very rapidly by quenching in water. It is workable then for about 45 minutes, after which time it becomes hard again.

For ferrous metals, the annealing method most commonly used, if a controlled atmosphere furnace is not available, is to place the metal in a cast iron box, and to cover it with sand or fire clay. Packing this material around the metal prevents oxidation. The box is then placed in the furnace, heated to the proper temperature,

held there for a sufficient period, and then allowed to cool slowly in the sealed furnace.

Instructions for annealing the more common metals are given in the following paragraphs.

CAST IRON.—Heat slowly to between 1400° and 1800° F, depending on composition. Hold at the specific temperature for 30 minutes, and then allow the metal to cool slowly in the furnace or annealing box.

STAINLESS STEEL (8.5-22).—Heat to between 1650° and 1750° F. Do not soak; that is, leave the metal in the furnace only long enough to be heated to the prescribed temperature. Cool slowly to room temperature.

STAINLESS STEEL (18-8).—For full annealing, heat to between 2000° F and 2200° F. Cool rapidly. For partial annealing, heat to between 1600° and 1700° F.

COPPER.—Heat to 925° F. Quench in water. A temperature as low as 500° F will relieve most of the stresses and strains.

ZINC.—Heat to 400° F. Cool in open, still air.

ALUMINUM.—Heat to 750° F. Cool in open air. This reduces hardness and strength but increases electrical conductivity.

NICKEL-COPPER ALLOYS— INCLUDING MONEL.—Heat to between 1400° and 1450° F. Cool by quenching in water or oil.

NICKEL-MOLYBDENUM-IRON and NICKEL-MOLYBDENUM-CHROMIUM ALLOYS (Stellite).—Heat to between 2100° and 2150° F. Hold at this temperature a suitable time, depending on thickness. Follow by rapid cooling in a quenching medium.

BRASS.—Annealing to relieve stress may be accomplished at a temperature as low as 600° F. Fuller anneals may be accomplished with increased temperatures. Larger grain size and loss of strength will result from too high temperatures. Do not anneal at temperatures exceeding 1300° F. Brass should be slowly cooled to room temperature. Either wrap the part with asbestos cloth, or bury in slaked lime or other heat-retarding material.

BRONZE.—Heat to 1400° F. Cool in open furnace to 500° F, or place in a pan to avoid uneven cooling caused by draft.

HARDENING

Many tools and pieces of equipment must be hardened before use. Cutting tools, chisels, twist drills, and other tools must be hardened so that they can retain their cutting edges. Surfaces of roller bearings, parallel blocks, and armor plate must be hardened to prevent wear and penetration. Hardening is used to increase tensile strength as well as to increase hardness. Since hardening increases the brittleness of the material, most alloys are tempered after being hardened.

Steels are hardened by being heated to a temperature just above the upper transformation temperature, soaked long enough to ensure a completely austenitic (a solid solution of carbon or iron carbide in iron) structure, and then cooled rapidly. If maximum hardness is to be developed, the austenite must be transformed to martensite. Martensite is extremely hard and strong and has great resistance, and it has practically no machinability.

Carbon steels are usually quenched in brine or water, in order to ensure rapid cooling. The production of martensite in a plain carbon steel requires that the steel be cooled to below 1000° F in less than 1 second, and that the remainder of the cooling be quite rapid. If more than 1 second is taken for the first part of the cooling (to below 1000° F), some of the austenite will transform into fine pearlite. Pearlite varies in hardness, but in any case it is much softer than martensite. If the purpose of the hardening is to develop something less than maximum hardness, the first part of the cooling (to below 1000° F) must still be accomplished within 1 second; then the remainder of the cooling must be done at a somewhat slower rate.

The rate of quenching alloy steels depends upon the composition of the material. In general, a slower quench is used for hardening alloy steels than is used for hardening plain carbon steels.

Various quenching mediums are used to produce the desired end results. The more common quenching mediums are oil, water, and brine. When water or brine is used, the temperature of the bath must not be allowed to rise above 100° F. Generally, 60° F to 90° F is the best temperature for these quenching medi-

ums. Above 100° F water begins to lose thermal conductivity, and thus, its cooling properties are reduced.

The plain carbon steels are generally quenched in water or brine; brine is preferred because it has less tendency to cause steam pockets to form. Steam pockets may cause soft spots or uneven stresses. These steels require a very active agitation, or shaking action, when being quenched. The agitation removes the steam bubbles from the surface of the metal. When the quenched material reaches about 200° to 250° F, or a temperature low enough to dry the material thoroughly without too much sizzle, it can be removed from the water and tempered immediately.

The alloy steels, with the exception of the high alloy air-hardening steels, are generally oil quenched. The oil bath should be maintained at a temperature of 100° F to 130° F. At this temperature the heat-treating oils have a higher viscosity and therefore a better and more uniform cooling effect.

Although steels must be heated and soaked so that the structure becomes completely austenitic, care must be taken to see that they are not overheated and that they are not held too long at temperature. Using too high a temperature or too long a soaking period coarsens the grain structure.

TEMPERING

After hardening, most alloys are tempered to reduce brittleness and to relieve some of the high internal stresses developed during hardening. Tempering always follows, rather than precedes, the hardening process. Tempering is occasionally done after materials have been normalized, but its major use is after hardening.

(NOTE: Normalizing is sometimes used as a preliminary step before full annealing and also may be followed by tempering, particularly when certain steels tend to become brittle when normalized.)

In high speed steels, tempering increases hardness. In most other materials, however, tempering causes an unavoidable loss of some hardness. The amount of hardness removed by tempering depends upon the tempering temperature; the higher the temperature, the softer the material will be.

Tempering is always done at temperatures below the lower transformation point. In this respect, tempering differs from hardening, annealing, and normalizing, which all involve heating the material to temperatures above the upper transformation point.

The temperatures used for tempering are selected on the basis of the properties required in the final product. For example, permanent magnets are tempered at 212° F because they must retain considerable strength and hardness. Casehardened objects are also tempered at relatively low temperatures (212° to 400° F) because the surface of such objects must remain hard. Many cutting tools are tempered at 430° F or below so that they will retain hardness. Battering tools must have great impact resistance and must be able to cut or penetrate metal; therefore, battering tools are tempered between 450° and 600° F even though the higher temperatures mean some sacrifice of hardness in order to produce impact resistance. Springs are tempered between 600° and 900° F because the property of elasticity is more important in a spring than the property of hardness. Tools made of high speed steels are tempered at 1050° to 1100° F. Note, however, that with high speed tools, the high tempering temperature increases, rather than decreases, hardness. This increase in hardness occurs because high speed steels retain austenite during quenching; when the hardened steel is tempered, the austenite changes to martensite.

Since tempering utilizes temperatures below the lower transformation point, the rate of cooling generally has no effect upon the structure of the material. However, some nickel-chromium steels and a few other special steels become brittle if they are heated to the tempering temperature and then allowed to cool slowly. These steels, which are often called "temper brittle" or "blue brittle" steels, must be quenched rapidly from the tempering temperature in order to prevent brittleness. In general, however, steels are cooled slowly from the tempering temperature by cooling in still air.

Tempering is usually done before the material has completely cooled from the hardening process. The holding time at temperature varies according to the thickness of the material, but the minimum time is about 1 hour. If the part is more than an inch thick, the holding time should be increased by about 1 hour for each additional inch of thickness.

BASIC REPAIR PROCEDURES

To perform the basic procedures involved in the repair of gages, instruments, watches, clocks, and office machines, you must find a logical approach to any repair problem which you, as an Instrumentman, are assigned to accomplish. To handle such a task properly, use all available information (plans, diagrams, and manufacturers' instructions), follow a logical sequence in disassembling a damaged item, cleaning it, and analyzing the damage, remove damaged parts, and decide whether parts must be repaired or replaced with new parts, and follow a recommended procedure in reassembling the item. Observe all appropriate precautions in connection with lubrication; use correct lubricants, avoiding lubrication of items that should not be lubricated. Refinish repaired items, using appropriate paints, thinners, and preservatives, and observe all appropriate precautions in connection with refinishing, such as not painting things that shouldn't be painted.

The information which follows supplements that given previously in this rate training manual.

CLEANING AND INSPECTING PARTS

When you start to overhaul and repair an instrument, refer to the notations made on the casualty analysis sheet for it prior to and during disassembly; and use this information as you proceed with the repair process.

The first phase of overhaul of the instrument is cleaning of mechanical parts. Always use approved cleaning solvents, which may be slightly toxic and irritating to your skin and necessitate cleaning in well ventilated spaces only. Avoid prolonged contact of the hands with the solvent. The safest policy is to use solvents only in a space specified for their use.

A cleaning machine, shown earlier in this rate training manual, is excellent for cleaning some mechanical parts of instruments. (An electric motor in the machine revolves a basket of parts a sufficient amount of time in an approved cleaning solvent and thus thoroughly cleans the parts. The second step in this process is to put the clean parts into another basket and rinse them in a container of approved rinsing solution. The final step (usually) in this cleaning process is to wash off the rinsing solution and dry the parts in the machine.)

Another type of instrument cleaning machine agitates solvent around the parts by vibration. The newest types of cleaning machines employ an ultrasonic oscillator to act on an approved liquid cleaning agent and thereby clean the parts.

NOTE: When you use a cleaning machine, follow the instructions listed in the manufacturer's technical manual. If you do not have this manual, consult your shop supervisor.

If your shop does not have a cleaning machine, use a stiff-bristle brush to clean instrument parts in a tank of cleaning solvent. This is one of the best and simplest methods for cleaning some (if not all) instrument parts. Some solvents leave an oily residue on clean parts and you must remove it by rinsing the parts in an approved degreasing agent. Traces of oil on the interior of an instrument may render the instrument useless.

After you clean instrument parts, inspect them for traces of lubricants, grease, or dirt. Scrape off dirt not removed during the cleaning process.

CAUTION: Do NOT scrape bearing surfaces. As you examine each cleaned part, look for defects previously hidden by dirt, wax, or grease; and also check them for corrosion. Replace badly corroded parts.

Place the cleaned parts you intend to use in a suitable, clean container and cover the container to protect the parts from dust and dirt.

REPAIR CATEGORIES

Now that you have cleaned and inspected the parts of the instrument undergoing repair, proceed **IMMEDIATELY** with the repairs. The repair process generally consists of three phases or categories: (1) repair and refitting of old parts, (2) using a new part (replacement) from stock, and (3) manufacturing and refitting a new part. Each of these categories is discussed in some detail in the following pages.

Repairing Old Parts

Repair reusable old parts, as necessary, and refit them into the instruments from which you removed them. The repairs which you may have to make on a part are discussed next.

If a part must be straightened or reformed to its original shape, strike it carefully at the proper place with a soft-faced hammer. **CAUTION:** Give the part necessary support before

you strike it, lest you inflect further damage upon it.

If a part is broken, repair it by soldering, brazing, or welding. When pieces of a broken part are missing, replace the part.

Dress up scratched, burred, and dented parts, in accordance with prescribed shop procedures.

Use much care when you repair parts, to prevent damage to precision bearing surfaces machined on them. Use a stone or a bearing scraper to remove burrs from a bearing surface, and be careful to remove only as much metal as is essential to do a good job. Do NOT file a bearing surface, for filing may completely ruin it.

When you complete repairs on an instrument part, refit the part on the instrument and check its action and/or operation for accuracy. If necessary, scrape off a slight amount of a surface in order to make a part fit properly; and redrill undersized holes and make other necessary changes of your repair job in order to have the part fit correctly. After you fit a part, **DO NOT FORGET** to make an assembly mark on it to indicate direction of installation.

CAUTION: Reassembly of an instrument containing improperly fitted parts may necessitate unnecessary subsequent disassembly on part or all of the instrument.

Replacement Parts

Sometimes a part is damaged to such an extent that it must be replaced with a new part. One source of replenishment is from stock, for some purposes only.

When you receive a replacement part from stock, try it for proper fit in the instrument or assembly. If it does not fit, take necessary action, including machining. A manufacturer, for example, does not drill dowel pin and screw holes; so you must drill them of correct size wherever required. A manufacturer also makes bearing parts slightly oversized, so that you can fit them properly by hand. Do not forget to make assembly marks on the new parts after you fit them, to ensure correct fitting of them into the instrument later.

Manufactured Parts

Occasionally, your shop supervisor can have parts made by submitting an intershop job order; but there will also be times when you will be

compelled to manufacture parts. Use information on the old part, or its name, to locate the blueprint. Use its dimensions to make or procure a new part when the blueprint is unavailable.

MISCELLANEOUS REPAIRS

When you gave the instrument on which you are working a pre-disassembly inspection, you perhaps noted undamaged moving parts in the instrument which were dry, tight, grinding, or rough in action. You also perhaps found in some instances a combination of these malfunctions, and even others not mentioned here.

When you effect miscellaneous repairs on an instrument, look for all types of trouble and remedy it, including lack of or dirty lubrication, excessive or insufficient clearances, incorrect alignment, and improper assembly. If the cause of malfunctioning is not readily apparent, proceed as follows:

1. Clean all parts of the bearing assembly.
2. Make a trial assembly, but do not force parts.
3. Check parts for proper clearance in order to determine the cause of binding or excessive lost motion.

CLEANING AND PAINTING PARTS

Having completed all authorized repairs to your instrument, you are now ready to accomplish essential cleaning prior to painting. Reclean all parts on which you made repairs, to remove traces of moisture, dirt, metal chips, and grease from its surfaces. If a part does not require painting, put it in the container with other cleaned parts of the instrument. Those parts which require painting have the old paint on them, and you must remove it before you apply a new finish. The procedure for doing this follows.

REMOVING OLD PAINT

There are two types of approved paint remover: (1) BRUSH-ON, and (2) PAINT AND CARBON, each of which is discussed in some detail next.

Brush-on paint remover dissolves synthetic-bristle brushes, so use a natural-bristle brush and brush it on the painted surface of an instrument part. Leave the paint remover on the part as long as necessary for it to dissolve the

paint and then wipe it off. Finish the job by rinsing the part in lacquer thinner or benzene to remove wax used in the remover as one of the ingredients.

Because it is difficult to wipe brush-on paint out of holes and corners, you will experience some difficulty in using it.

Paint and carbon removers are available through Navy supply channels and also commercially. They are designated as SUPER cleaners. Besides removing paint, they remove heavy carbon, grease, varnish, and sticky gums.

You will obtain the best results with a paint and carbon remover by putting at least 10 gallons in a stainless steel tank and soaking the parts as long as necessary in it. Then wash each part with hot water, remove the water with a compressed air hose, and bake it briefly in and oven. It is then ready for painting.

CAUTION: Paint and carbon removers are not explosive or flammable, and they contain a chemical seal-top layer which prevents evaporation; but use them **ONLY** in well ventilated spaces and protect your eyes with goggles.

REMOVING CORROSION

Paint removers do not eliminate corrosion from instrument parts, so it must be removed with an approved corrosion removal compound, available through naval supply channels and commercially. **NOTE:** Use only Navy approved commercial products.

Always follow the manufacturer's instructions when you use any product, and protect yourself by following safety precautions.

Corrosion generally eats into a part, and the best way to remove it is to soak the part for a sufficient amount of time in a tank (stainless steel) of the compound.

If you do not have an approved corrosion removal compound, you may make some (for different metals) by using the following formulas:

1. To make a corrosion removal compound for CAST IRON AND STEEL, use a 50 percent solution of sulfuric acid and distilled water (about 150° F). Then dip the corroded metal parts in the warm acid for about 5 seconds and wash them immediately in several changes of hot water.

CAUTION: Do not handle chemicals until you understand the safety precautions which pertain to them. **NEVER USE ACID ON BEARINGS, or GEAR TEETH.**

2. You can make a corrosion removal compound for brass by using the following formula:

Water (pure, distilled).	491 cc
Sulfuric acid (concentrated). . .	435 cc
Nitric acid (concentrated). . . .	72 cc
Hydrochloric acid (concentrated)	2 cc

If a brass surface is bright in spots, there is probably some clear lacquer on it. Submerge the part in paint remover and then rinse it with hot water. Continue by dipping the part in the correct amount of the corrosion removal solution for 4 or 5 seconds, rinsing it in water, drying thoroughly with an air hose, and applying at least one coat of clear lacquer before the surface oxidizes. NOTE: Do not use lacquer if the part requires paint.

CAUTION: Do not use a brass dip on bearing surfaces.

3. To clean corrosion from aluminum, dip it for 5 to 10 seconds in a 10 percent solution of sodium hydroxide (lye) at a temperature of about 150° F and wash the lye off immediately with hot water.

You can also use some non-chemical methods for removing corrosion and giving a bright, clean finish to metal parts. These methods involve types of abrasives, wire brushes, buffing wheels, and abrasive cloth, listed in the order of discussion.

1. REMOVING CORROSION WITH A WIRE BRUSH. There are two types of wire brushes which you may use to remove corrosion from metal, rotary-power and hand.

CAUTION: To prevent damage to your eyes, wear your goggles to protect them from flying wire. Do not use a wire brush on a bearing surface or an engraved part.

To use a rotary-power wire brush, hold a part against the wheel with enough pressure to force the moving wire bristles into the corrosion and keep the part moving slowly and evenly against the wheel. Run the wheel from the center of the part toward the edges, to ensure thorough cleaning of the edges. Use a hand wire brush, emery paper, or a scraper to remove corrosion from the inside corners of the part.

2. REMOVING CORROSION WITH A BUFFING WHEEL. A buffing wheel gives a part a brighter, polished finish than a wire brush (wheel), but it will not remove heavy corrosion. For this reason, do not use these wheels on large areas, but use them to polish metal parts which must remain bright.

Use a polishing compound with a buffing wheel, and polish a part until you have the desired brightness and polish. Then remove the remains of the polishing compound with a solvent, dry the part thoroughly, and apply at least one coat of clear lacquer.

NOTE: To speed up the buffing process, clean the parts first in a corrosion remover.

3. REMOVING CORROSION WITH ABRASIVE CLOTH. You can remove corrosion from metal with an abrasive cloth in the following manner:

a. Polish flat pieces by hand on crocus cloth (embedded with an oxide of metal) laid on a flat surface.

b. Polish irregular pieces which you cannot buff on a wheel by hand. Use wood or metal in the jaws of a vise to protect these pieces and secure them **ONLY** as tightly as essential. To polish a piece in the vise, use a strip of fine emery cloth and complete the job with a piece of crocus cloth, to remove grains produced by the emery cloth.

c. Put small, round parts of an instrument in the collet of a lathe and (with the lathe running at high speed) touch the parts lightly with emery cloth or crocus cloth to the extent necessary to obtain the polish desired.

CAUTION: Do not use abrasive cloth on bearing surfaces. When a bearing surface has deep pits caused by corrosion, it is worthless; the bearing is ruined. Use a non-abrasive cleaner to remove light corrosion from the surface of a bearing. Unless there are provisions provided in the construction of a bearing for refitting it, and you can do this in your shop, never remove metal from a bearing surface. When you remove corrosion from a bearing surface, rub it off carefully with crocus cloth or a fine paste of clock oil and pumice, or by scraping.

PAINT PROCEDURE

After you remove corrosion from instrument parts, you are then ready to paint those which require paint. To protect the metal from rust and corrosion is most important for instruments used aboard ship, where salt spray and damp, salty air quickly corrode unprotected metals.

To improve appearance is also important. A good-looking, pleasing appearance of an instrument creates a good impression on all who

see and use the instrument. Inspection of painted surfaces of instruments is part of your mandatory inspection procedure.

Some paint manufacturers make lacquers and enamels which put a fine finish on instruments. Many instrument parts have a very smooth, hard finish which appears to be part of the metal itself. This finish is called AN-ODIZE, applied to the metal by an electrochemical process.

A baking enamel of high quality gives a hard, durable finish, but air-dried enamel is good for touching up or painting an instrument which cannot be subjected to heat in a baking oven. Lacquers have one outstanding characteristic, quick-drying, but they cannot resist chemicals and are therefore not as durable as enamels.

CAUTION: Never cover enamel with lacquer, because the lacquer loosens the enamel from its base and causes it to blister.

Paints which give a semigloss, black appearance and a hard, durable finish are used on parts which receive considerable handling, and on such small articles as knobs, handles, and pointers.

Always use clear lacquer on parts subject to corrosion but which are not painted, to protect their high polish.

Most paints and their thinners are flammable, and some are explosive; so use a spray booth with an explosion-proof exhaust fan. To prevent spontaneous combustion, put rags used for wiping up paints, oils, and thinners in a container with a self-closing cover and dispose of them completely as soon as practicable. Stow paint materials in a locker which will not tip over, and at a temperature less than 95°F, preferably—never over 95°F.

CAUTION: Permit no smoking in the spray room, and have a CO₂ fire extinguisher available in the room's equipment. Do NOT play with the air hose, or point it toward your own person or any one else.

When you paint with a spray gun (usually the case), mask bearing surfaces, threads, and holes to the interior of the instrument, from which you desire to exclude the paint. Tear off strips of the tape and put them over the surfaces of the bearings, with the edges of each successive strip (one side) slightly overlapping the last strip applied. Then trim off excess tape with a sharp knife or razor blade. Mask off also points on the instrument you do not wish to paint.

Punch holes in a small box top or piece of cardboard and stick the bodies of screws whose heads you desire to paint into the holes, to keep paint off the bodies of the screws. You can also place on the cardboard top small parts which you intend to paint on one side only. String parts which you desire to paint all over on small pieces of brass wire.

Preparing the Paint

Prepare both the primer coat and the finish coat in the same manner for use in a spray gun, as follows:

1. Stir the paint thoroughly in order to mix the pigment back into the liquid vehicles used to suspend it. Unless you do this, the paint will not cover surfaces with uniform thickness and will not have luster and the same color all over.

2. Thin thick paint before you put it into a spray gun; otherwise, it will clog the gun and not go through it. Use your experience and the manufacturer's instructions when you thin the paint to proper consistency. Dip a pencil vertically into the lacquer or enamel and then withdraw it. If the consistency is correct for spraying, the lacquer or enamel will run off the pencil in a smooth, thin stream. When thinning paint, however, do not add much over 20 percent of thinner to the paint, lest you get it so thin that it will not cover material properly. (Total volume of paint and thinner should be about 20 percent thinner.) After you add thinner, stir the paint thoroughly.

3. When you have the paint at the right consistency for spraying, strain it through several thicknesses of cheesecloth or medical gauze to eliminate lumps of undissolved pigment, dirt, and any other particles which could clog the spray gun and give a poor finish on your work.

Applying the Paint

Before you use a spray gun for the first time, seek good information concerning its operation, or closely follow the manufacturer's instructions for its use. Check the spray gun for cleanliness. If it is dirty or has old paint on the inside, disassemble it completely and soak the metal parts in a paint remover. Clean the baskets in lacquer thinner. **CAUTION:** Paint remover will ruin the gaskets. When you reassemble the spray gun, lubricate all moving parts.

Fill the canister of the spray gun with your prepared paint and turn on the air pressure, about 40 to 60 pounds per square inch, or as recommended in the manufacturer's technical manual for the gun. Then so adjust the gun that it delivers a fine spray with enough density to cover surfaces rapidly with a uniform, wet appearance. Then begin your spraying.

Hold the spray gun about 10 inches from your work and keep it moving horizontally, back and forth. Be sure to carry each swing off the gun out past the end of the work before you start back, to prevent piling up the paint near the edges of the work and subsequent sagging. Start at the top of a surface and work down, back and forth in horizontal motion, and cover the last old lap with about half of your new lap. If you follow this procedure, the paint will be uniformly thick over the entire surface.

After you finish a paint job with a spray gun, spray lacquer thinner over the gun to remove lacquer and enamel from the small openings. At the end of the day, if you use the gun last, completely disassemble the gun and wash all parts in lacquer thinner. Then dry, lubricate, and reassemble it so that there will be no delay of work the next day. The best time to clean a spray gun is while the paint on its surfaces is still wet.

NOTE: Your spray gun should have an air pressure and reducing valve with a water and oil trap (and filter) which should work correctly all the time. Drain this trap regularly. If water and oil get into your spray gun and paint, it will ruin the appearance of your work; and the lacquer or enamel will not dry.

Following is a list of difficulties sometimes experienced with a spray gun, with the reason for each difficulty given.

1. **FINISH REFUSES TO DRY.** You forgot to remove the oil and grease from the metal surfaces of your work, or from your air supply.

2. **FINISH COVERED WITH TINY ROUGH SPOTS.** There was too much dust or moisture in the air, or in the paint or spray gun.

3. **FINISH HAS SMALL CIRCULAR MARKINGS.** There was water in the air hose, or water dripped or condensed on the work before it was completely dry.

4. **FINISH SHOWS HORIZONTAL STREAKS.** Your spray was too fine and the last lap had started to dry before you applied the next one, or you forgot to cover half of each old lap with the following lap.

5. **FINISH IS UNIFORMLY ROUGH.** The spray was too fine, or you held the gun too far from the work, and the droplets began to dry before they hit the work.

6. **THE FINISH HAS LUMPS OR BLOBS.** The spray gun or hose line was dirty, or you forgot to strain the paint.

7. **THE FINISH RUNS.** The consistency of the paint was too thin.

8. **THE FINISH SAGS.** You moved the gun too slowly or held it too close to the work.

9. **THE FINISH SHOWS ORANGE-PEEL EFFECT.** The consistency of the paint was too thick, your spray was too fine, or you held the gun too far from the work.

When you intend to paint and bake instrument parts, remove all masking tape before you put the parts in the oven. If you cannot remove the tape before you bake the parts, remove it immediately upon taking the parts out of the oven. This is also a good time to apply engraver filler, commonly called MONOFILL, a soft, wax-base compound (generally in crayon form) used to fill in and accentuate engraved index lines and numbers. While the part is hot, the filler flows easily into an engraving. When the part cools, wipe off the excess filler with a soft cloth.

MANUFACTURING

Before a striker can qualify for advancement to Instrumentman 3, he must know how to work from schematic diagrams for making parts; he must know what power tools to use for making flat springs, levers, pillars, bushings, and shafts; he must understand bench grinder operations; and he must be able to manufacture a spring hook, using a bench grinder and an alcohol torch. He must also know how to manufacture an instrument screwdriver and a drill and tap gage; he must be able to make a spring from flat spring steel or steel wire stock; and he must know what handtools and power tools to use in making a drill and tap gage.

Before you start to make anything, prepare (or have prepared) a sketch or schematic diagram giving the specifications for the part and the procedure for making it. An IM1 or an IMC will probably make the diagram for you, but you should go over it with him and have him explain everything to your satisfaction. You need to know how to start a job and how to proceed with it, step by step, until it is finished. If you

know how to prepare sketches for and are able to make some instrument parts, you will in time learn how to make most of the other parts which require replacement. Bear in mind, however, that you will attain proficiency in making these parts **ONLY** through experience in instrument shops.

The information which follows deals with a few typical manufacturing problems. Additional information concerning manufacturing procedures can be obtained from manufacturers' technical manuals for specific equipment.

MAKING INSTRUMENT SCREWDRIVERS AND BITS

Under normal circumstances, you will get all your screwdrivers through supply channels from typewriter manufacturers. Some repairmen, however, prefer to make most of their own screwdrivers. A screwdriver is not difficult to make if you use the following procedure:

1. Select a piece of drill rod of the desired size, 1/8", 3/16", and so on, and cut it for the length of screwdriver shaft you desire.

2. Grind one end of the rod on the shop emery wheel to make the screwdriver blade. Taper the blade back to the body of the shank. Grind the end of the blade square, at right angles to the shank, and with both sides approximately parallel. Recheck the procedure for grinding a screwdriver blade in figure 14-3. When you have the blade ground correctly, flatten the other end of the shaft (shank) and insert it into a handle.

3. Harden the blade to increase its tensile strength. To harden, heat the blade until it is a cherry red and immediately quench it in fresh water. Brine is generally used to quench the heat from carbon steel; and oil is used to quench the heat from steel alloys. Hardening requires that the metal be cooled rapidly enough to prevent loss of hardness and cracking or warping of the metal.

4. Temper the blade to reduce brittleness and to relieve some of the high internal stresses developed during the hardening process. (Tempering should always follow the hardening process, and before the metal cools completely.) In high speed steels, tempering increases hardness; in other type steels, tempering causes an unavoidable loss of some hardness.

The amount of hardness removed by tempering depends upon the tempering temperature; the higher the temperature, the softer the metal will be. Casehardened objects are tempered at relatively low temperatures (212°F to 400°F). Many cutting tools are tempered at 430°F or below in order to retain hardness. To obtain a higher degree of elasticity, springs should be tempered at temperatures between 600°F and 900°F. Tools made of high speed steels should be tempered at 1050°F to 1100°F.

Remember that some nickel-chromium steels (and a few other special steels) become brittle if they are heated to the tempering temperature and then allowed to cool slowly.

5. Test the screwdriver blade by tightening several screws. If the tip of the blade breaks or twists, it was not properly tempered.

MAKING SPRING HOOKS

Certain types of spring hooks used by the Navy are illustrated in figure 14-9. The length, type, and strength of a spring hook are determined by the purpose for which the hook is intended. For obvious reasons, some must be longer and heavier than others, and the shape of hooks must vary in accordance with needs.

Suppose you desire to make a short spring hook with a fine hook on one end. What is the procedure?

1. Make a sketch of the hook, and list all specifications, including the size of the hook, and the style of the hook desired.

2. Select a piece of drill rod of the size specified on the diagram and cut a piece of the correct length.

3. Firmly secure the cut piece of drill rod in a vise, with about 1-1/2 inches of one end protruding from the side of the closed jaws.

4. Measure the length of the hook bill specified on the diagram and make a mark at this point on the rod with a small, triangular file.

5. With a file of about the same width as the length of the hooked bill (before bending), file the hook bill all around with rocking strokes until you have cut away about half the diameter of the metal. Then use a smaller, flat file to put a sharp point on the end of the bill.

6. With a pair of needle-nose or duck-billed pliers, bend the hook in the manner necessary to get the shape specified on the sketch.

7. Polish the bent bill with emery cloth.

You can also use a power grinder to put the bill on a spring hook, but be careful that you do not grind off too much of the metal. When using some metals for making a hook, it is also a good idea to heat the bill with an alcohol torch before you bend it to the desired shape. The hot metal bends easily without breaking. After forming the spring hook, harden and temper it the way you tempered a screwdriver.

It is possible to make some spring hooks with galvanized wire. Cut the wire of the length specified on your sketch and make the hook on an anvil. Use a file, pliers, and emery cloth for shaping and finishing the file.

MAKING DRILL AND TAP GAGES

Drill sizes are indicated by inches, letter, and number. Nominal inch sizes run from 1/16" to 4", or larger, in 1/64-inch increments. Letter sizes run from A to Z (0.234" to 0.413"). Number sizes run from No. 80 to No. 1 (0.0135" to 0.228").

Dies and taps for cutting machine threads are made according to three basic sets of standards: American National, American Standard, and Unified Thread Standard. Many of the machine threads established by these sets of standards are interchangeable.

The NPT, which formerly stood for National Pipe Thread, is still used and refers to the new name for the same thread, American Standard Taper Pipe Threads. The standard taper of pipe threads is 3/4-inch per foot. The number of threads per inch varies according to the size of the pipe, as follows: 1/16" and 1/8" pipe have 27 threads per inch; 1/4" and 3/8" pipe have 18 threads per inch; 1/2" and 3/4" pipe have 14 threads per inch; 1" and 1-1/4", 1-1/2", and 2" pipe have 11-1/2 threads per inch; and 2-1/2" pipe and larger has 8 threads per inch.

In addition to the above thread standards, the National Miniature (NM) Screw Threads standard is intended for general purpose fastening screws and similar uses in watches, instruments, and miniature mechanisms.

There are 14 sizes, systematically distributed to provide a uniformly proportioned selection over the entire range. The values of all dimensions are supplied in metric and inch units, but the standard is basically metric. Metric units are stipulated for all formulas, and the inch dimensions are derived by conversion of the unrounded metric values, using the conversion factor 25.4 per inch.

Some basic and design sizes of the National Miniature Screw Threads standard are shown in the accompanying chart.

<u>Size</u> <u>Designation</u>	<u>Threads</u> <u>Per Inch</u>	<u>Diameter</u> <u>(in.)</u>
30NM	318	0.0118
35NM	282	.0138
40NM	254	.0157
45NM	254	.0177
50NM	203	.0197
55NM	203	.0217
60NM	169	.0236
70NM	145	.0276
80NM	127	.0315
90NM	113	.0354
100NM	102	.0394
110NM	102	.0433
120NM	102	.0472
140NM	85	.0551

In your work as an Instrumentman, you will generally use the screw threads given in the National Miniature standards. The same is true for taps and dies, as regards sizes.

A twist drill and machine screw tap gage is illustrated in figure 14-25. Note the three columns of numbers on the left of the gage. The first column gives the size of tap, the second column gives the tap drill size, and the third column gives the body drill size. The decimal equivalents for numbers in the three columns, horizontally, are indicated near the gage holes.

A simple twist drill gage is shown in figure 14-26. Note the three columns of holes and the numbers adjacent. This drill gage handles drill sizes 1/16" to 1/2" in 1/64-inch increments. The sizes of holes in a gage, of course, vary in accordance with the purpose for which the gage is to be used.

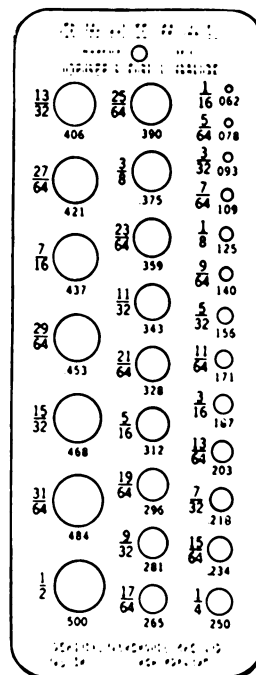
To gage a drill with a drill gage or twist drill and machine screw tap gage, insert the point of the drill into the hole which fits it snugly (without force) and read the decimal or fraction size near the gage hole.

The first thing you need in making a drill and tap gage is a diagram of the dimensions and data to be inscribed on it. The best plan is to make a sketch of the gage on drawing paper. Show the location and sizes of all holes to be drilled in the gage. Use a commercial drill and tap gage, if available, as a sample while you are making your diagram, which must be correct and exactly as you want the finished gage.

After you complete your diagram, select a piece of stainless steel, secure it firmly in a vise, and then cut it with a hacksaw to the dimensions specified on your diagram. Smooth the edges with a grinder and polish them with a hand stone and emery cloth. You must use a hard metal to make the gage, to prevent damage to its drilled holes by hard-metal drills inserted into them.

The next step in making the gage is to drill the holes in the gage with a power drill. Use a center punch to start each hole exactly where it belongs, in accordance with your diagram. Before you start to drill the first hole, you can use the center punch to indicate on the metal the location of all holes shown in the diagram and then make measurements to determine if they are properly placed. Use a drill of exact size for drilling each hole; otherwise, the gage will not be accurate. Keep the drill perpendicular to the gage while drilling a hole. When finished with the drilling, remove burrs from the edges of holes with emery cloth.

One of the most important phases in making a drill and tap gage is the inscribing or stamping of data on the gage. You can put the information on the gage with a scratchawl or a scribe, but this is a slow and tedious process. If your



61.35B

Figure 14-26.—Twist drill gage.

ship has an engraving shop, have this shop put the data on the gage from your diagram.

MAKING SPRINGS

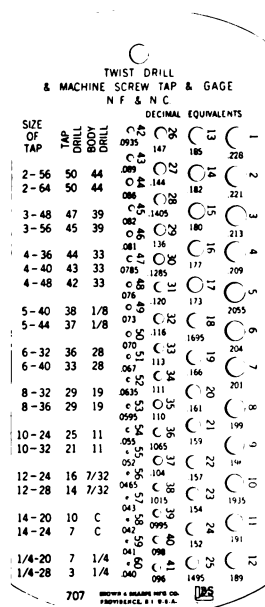
One of the things you must be able to do before you can advance in rate is to manufacture a spring from flat, spring steel or steel wire stock. After you make it, you must be able to harden and temper it.

Suppose you have a requirement for a new click spring for a clock. What procedure should you follow in making it?

1. Select a piece of plain, flat, carbon steel stock a little thicker than the thickness of a finished click spring (to allow for finishing) and about 6 inches long.

2. Clean one end of the piece of metal with an emery buff and cover it with beeswax to form a wax film. Then place an old clock click spring on the clean end of the stock, as illustrated in figure 14-27.

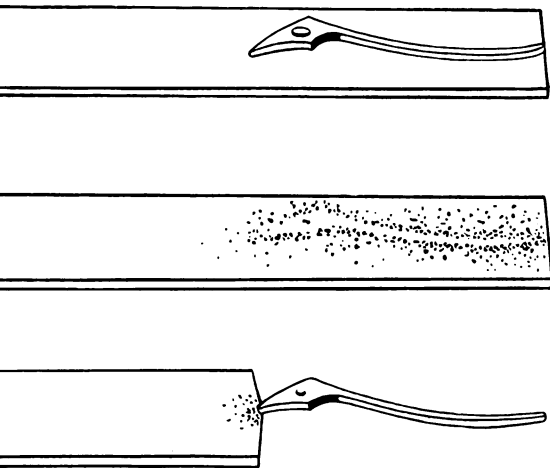
3. Heat the end of the stock on which you have the beeswax and the old spring until the stock turns blue.



61.35A

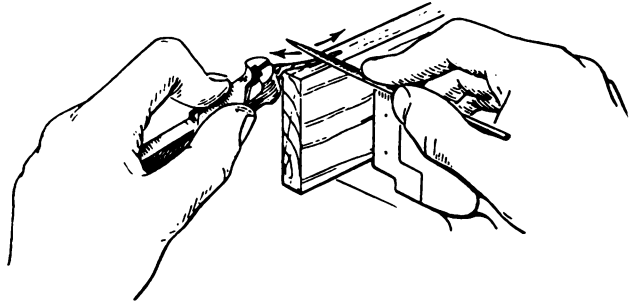
Figure 14-25.—Twist drill and machine screw tap gage.

4. Remove the old spring from the stock blow on the heated end of the stock to cool you will then see the outline of the old spring etched in the beeswax on the steel stock (middle of fig. 14-27).
5. Secure the steel stock in a vise and use a half-round file to file the metal away from the edge of the new spring etched on the stock. (figure 14-28).
6. When you have the spring filed into shape, pull it away from the piece of steel stock (bottom of fig. 14-27).
7. Secure a piece of soft wood in a vise to support the click spring as you hold it with pliers to complete the rough filing.
8. To drill the hole(s) in the head of the click spring, clamp the spring to a flat piece of wood and secure it in a pin vise. Then drill the hole through both pieces of metal (extra piece of metal prevents breakage of drill).
9. Secure a piece of soft wood in a bench vise in the manner shown in figure 14-29 and insert the click spring to the wood with a short screw nail or pin.
10. With a fairly smooth file, file one side of the spring flat and smooth. Then turn the spring over and file the other side. Remove the burrs and finish the edges of the spring with a fine emery cloth.
11. Secure the spring in a vise and counter-drill the screw hole so that the head of the screw will be flush with the surface of the spring.



61.36AX

Figure 14-27.—First steps in making a click spring for a clock.



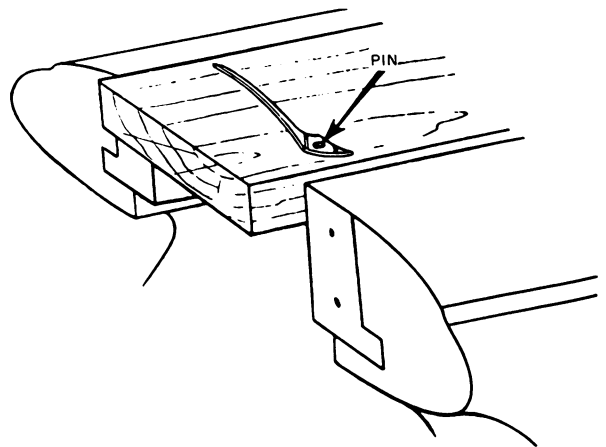
61.36BX

Figure 14-28.—Draw-filing the edges of a click spring.

when the screw is inserted to hold the spring in position.

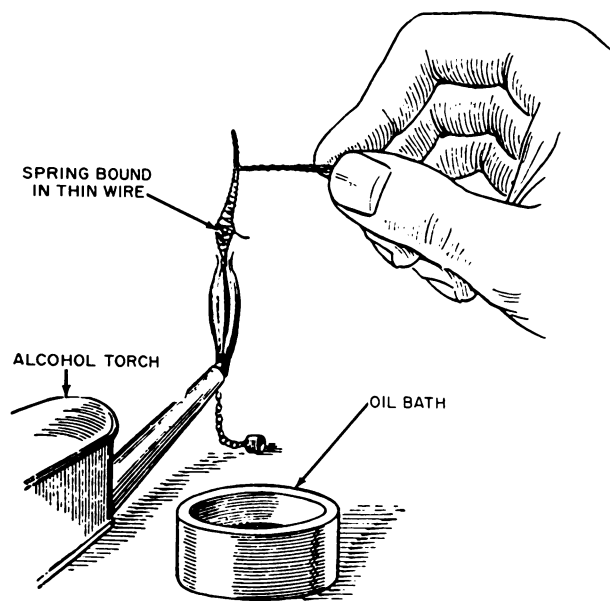
12. To harden the spring when it is finished, use the procedure illustrated in figure 14-30. Before you heat the delicate spring, bind it tightly with binding wire (to prevent distortion during cooling), with one end bent to a 90° angle for a handle. Then hold the spring in the blue portion of the flame of an alcohol torch and heat it to a cherry-red color. Remove the spring from the flame and cool it slowly in an oil bath (fig. 14-30). Heating alters the basic physical structure of the metal; quenching fixes the structural changes in such manner that the metal remains hard after it is cooled.

13. To temper the spring, remove the binding wire and reheat it to a pale straw color. Cool the spring slowly in air.



61.36CX

Figure 14-29.—Click spring pinned to wood block.



61.36DX

Figure 14-30.—Procedure for hardening and tempering a new click spring.

14. Finally, bevel the edges of the spring with a burnisher, and then chamfer and burnish the top edge of the screw hole. A completed click spring is shown in figure 14-31.



61.36X

Figure 14-31.—Finished new click spring.

SAFETY PRECAUTIONS

Working safely is the first essential one should learn before being taught how to use required tools for specific jobs, as well as machinery and equipment. Safe working habits cannot be bought or manufactured; they must be learned through practice.

You must observe manufacturers' recommended precautions when operating general purpose test equipment, and handling, stowing as well as identifying compressed gas cylinders, when required. You must know the safety precau-

tions concerning pneumatic and hydraulic system isolation valves in MIRCS; therefore you should know the location of these values aboard ship. When charging, boosting and bleeding pneumatic and hydraulic test equipment, piping systems and components, you must have a knowledge of the safety precautions to be observed in accordance with manufacturers' recommendation for specific equipments or systems.

The sections which follow deal with the important safety precautions and emergency procedures applicable to repair and manufacturing processes.

PRECAUTIONS IN USE OF TOOLS

Keep power tools used in the instrument shop in an excellent state of repair. Clean them thoroughly after use, and always put the portable types in their storage cases or in a special storage cabinet. Use an approved solvent to remove grease from taps, dies, and drills. Wipe motors with a clean, dry cloth—after you have turned off the power switch or pulled the power cord. Never disassemble an electric motor. Cleaning the interior of an electric motor is the direct responsibility of the Electrician's Mate.

Do not abuse power tools through improper use or careless maintenance. Take pride in your tools and always treat them as you would your own.

To protect yourself and others working adjacent to you, use special precautions when using a power drill, power lathe, and power grinder. In the first place, do not attempt to use these tools until you have had adequate instruction in their use and you have been authorized to use them. Experimentation with power tools can be dangerous to you and result in damage to the tools. If a power drill slips, you can easily injure a finger or a hand. Unless you firmly secure a piece of metal on which you intend to work in a power lathe, the metal may work out of position and injure you. Always use goggles or a face shield when buffing or grinding, or when there is danger of flying particles. There is no exception to this rule.

Do not use electrical equipment or machines with frayed or otherwise deteriorated insulation. Electrically driven portable machinery and fixed electrical equipment must have the frame grounded.

Aboard ship, electrically driven portable hand-tools may not be operated unless they are equipped with ground wire connections between their metal housings and the steel structure of

ip. There is no exception to this rule. These must be equipped with an approved type of plug. You must inspect the attached and plug of a tool before you use it, to make sure that the insulation and contacts are in good condition. Tears, chafing, exposed insulated conductors, and damaged plugs are sufficient reasons for replacement before the tool is safe to use. Portable hand electrical tools must be inspected and tested periodically (usually monthly) by a qualified Electrician's Mate to make sure that they are properly grounded and in good operating condition electrically. Any electrically powered handtools which have not been inspected by an Electrician's Mate must be considered unsafe for use.

PRECAUTIONS WHEN WORKING WITH ELECTRICAL EQUIPMENT

Safety precautions must always be observed by persons working around electric circuits and equipment to avoid injury from:

Electric shock.

Short circuits caused by accidentally placing or dropping a metal tool, ruler, flashlight or other conducting article across an energized line. The arc and fire which can be so produced on even relatively low voltage circuits can cause extensive damage to equipment and serious injury to personnel.

At the danger of shock from the 450-volt ship's service system is reasonably well minimized by operating personnel is shown by the relatively few reports of serious shock received from this voltage despite its widespread use. On the other hand, a number of shipboard injuries have been reported due to contact with high voltage circuits. Despite a fairly widespread but unfounded popular belief to the contrary, low voltage (115 volts and below) circuits are not dangerous and can cause death where the resistance of the body is lowered by moisture and especially when current passes through the heart. Shipboard conditions are particularly conducive to severity of shock because the body is often wet or in contact with the ship's metal structure and the body resistance may be low because of perspiration or damp clothing. Extra care is always needed.

Electrical safety is an all-hands job. For this reason, it is essential that all personnel understand the lethal nature of the hazard and be made

familiar with the electrical safety precautions and safe practices. Additional information, not covered in this section, can be obtained from articles 9600-21 through 9600-40 of NavShips Technical Manual.

After an accident has happened, investigation almost invariably shows that it could have been prevented by the exercise of simple safety precautions which are then posted for future guidance, but which never undo the consequences of the accident that has gone before. Always observe safety precautions and keep accidents from happening. Always remember that:

- (1) Electricity strikes without warning.
- (2) Hurrying reduces caution and invites accidents.
- (3) Taking time to be careful saves time in the end.

- (4) Taking chances is an invitation to trouble.
- (5) If you do not know the safe way, it pays to find out before exposing yourself to danger.

(6) Every electrical circuit, with but insignificant exceptions which definitely do not include circuits even as low as 35 volts and possibly lower, is a potential source of danger and **MUST BE TREATED AS SUCH**.

(7) Except in cases of emergency, never work on an energized circuit. (Before using any portable equipment, visually inspect it, looking for damaged or frayed cords.)

It must be considered that the circuit is energized until a personal check has been made to see that the switch is opened and tagged and the circuit has been tested with a voltmeter, or voltage tester.

(8) Energized switchboards are a great source of danger. No work shall be undertaken on switchboards (energized or deenergized) without first obtaining the approval of the Electrical or Engineer Officer. The Commanding Officer's approval shall be obtained prior to the commencement of work on an energized switchboard.

EMERGENCY PROCEDURES

As far as emergency procedures for electrical shock are concerned, artificial respiration and cardiac massage are emergency life saving techniques. Knowledge of these, together with certain power release and time precautions, may save someone's life.

Power and Time Release Precautions

All personnel should be made aware of the fact that a victim rendered unconscious by

electric shock should receive artificial respiration and that it should be started in a matter of seconds rather than minutes. To this end, the person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the man from his contact with the electricity in the quickest, safest way. This step, while it must be taken quickly, must be done with great care, otherwise there may be two victims instead of one.

W A R N I N G

DO NOT Attempt to administer first aid or come in physical contact with an electric shock victim before the voltage is cut off, or, if the voltage cannot be turned off immediately, before the victim has been removed from the live conductor.

This should be done in the case of a portable electric tool, light, appliance, equipment, or portable outlet extension by turning off the supply switch or by removing the plug from its receptacle. If the switch or receptacle cannot be quickly located, the suspected electric device may be pulled free of the victim by grasping the insulated flexible cable to the device and carefully withdrawing it clear of its contact with the victim. Other persons arriving on the scene must be clearly warned not to touch the suspected equipment until it is unplugged. Aid should be enlisted to unplug the device as soon as possible. Where the victim is in contact with stationary equipment, such as a bus bar or the contacts on a machine, he should be pulled free if the equipment cannot be quickly deenergized, or if considerations of military operation or survival prevent immediate shutdown of the circuits. The man can be quickly and safely cleared from his contact with the electricity by careful ingenuity.

For example, instead of taking time to look for a pair of rubber gloves for use in grasping the victim, the victim can be safely pulled free (if conditions are dry) by gasping him by slack in his clothing or by the leather of his shoes or by using your own belt. Use anything dry and nonconductive such as a stick or board to break contact. Instead of hunting for a rubber mat on which to stand, such nonconducting materials as deck linoleum, a pillow, blanket, mattress, dry wood, or coil of rope will suffice. In no case during the rescue should any part of the rescuer's person directly touch metal or metal structure or furniture.

Artificial Respiration

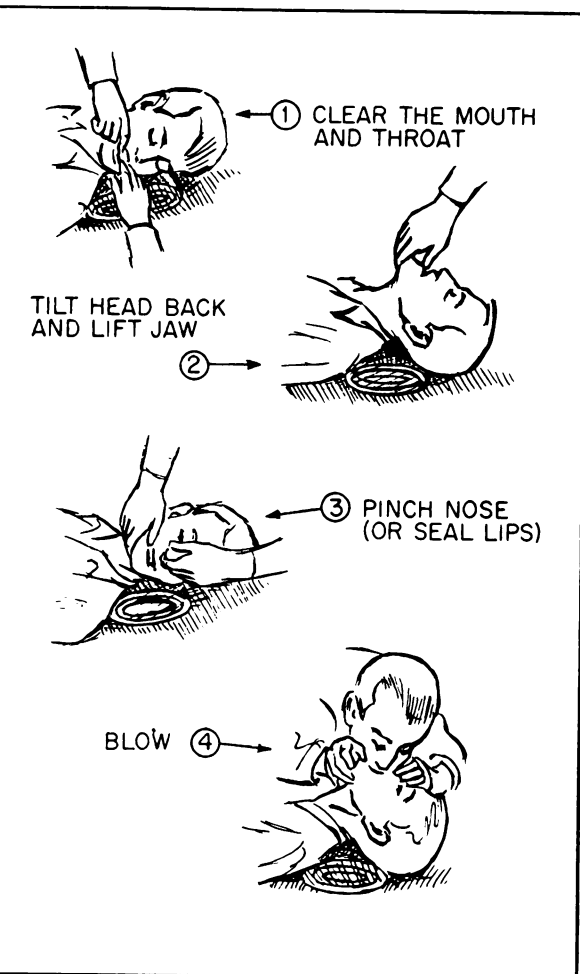
The following instructions on resuscitation were furnished by the Bureau of Medicine and Surgery. Artificial resuscitation after electric shock includes artificial respiration to reestablish heart beat and blood circulation.

To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth artificial respiration. (See figs. 14-32 and 14-33.) If there is no pulse, immediately apply heart massage also (fig. 14-34).

Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location.

ARTIFICIAL RESPIRATION MOUTH-TO-MOUTH OR MOUTH-TO-NOSE RESCUE BREATHING	
①	PLACE CASUALTY ON BACK IMMEDIATELY DON'T WASTE TIME MOVING TO A BETTER PLACE, LOOSENING CLOTHING, OR DRAINING WATER FROM LUNGS.
②	QUICKLY CLEAR MOUTH AND THROAT REMOVE MUCUS, FOOD AND OTHER OBSTRUCTIONS.
③	TILT HEAD BACK AS FAR AS POSSIBLE THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.
④	LIFT LOWER JAW FORWARD GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.
⑤	PINCH NOSE SHUT OR SEAL MOUTH PREVENT AIR LEAKAGE.
⑥	OPEN YOUR MOUTH WIDE AND BLOW TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.
⑦	LISTEN FOR EXHALATION QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.
⑧	REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.
* FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEK	

Figure 14-32.—Procedure for artificial respiration.



4.224

Figure 14-33.—Mouth-to-mouth resuscitation.

a roomier dryer location, or to loosen his clothing. Records show that seven out of ten victims of electric shock were revived when artificial respiration was started in less than 3 minutes after the shock. After 3 minutes the chances of revival decrease rapidly.

If desired, breathe into victim's mouth through a cloth or a handkerchief placed over victim's face. If assistance is available, take turns breathing into victim and massaging his heart.

Cardiac Massage

If the subject has suffered an electric shock and has no heart beat, he has had a cardiac arrest. This is demonstrated by finding a complete absence of any pulse at the wrist or

in the neck. Associated with this the pupils of the eyes will be very dilated, respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances, severe brain damage will occur in four minutes unless circulation is reestablished by cardiac massage. The closed chest cardiac massage method has been adopted as practical, and can be learned by anyone who is properly instructed, and requires only two hands. The object in closed chest cardiac massage is to squeeze the heart through the chest wall thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

The directions for cardiac massage are described in the paragraphs which follow.

Place subject on his back; a firm surface, such as the floor is preferred. Expose subject's chest. Kneel beside victim; feel for lower end of subject's sternum (breastbone); place one hand across breastbone so heel of hand covers the lower part; place second hand on top of the first so that the fingers point toward neck as in figure 14-34.

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the subject. It should be applied as smoothly as possible. With an adult subject, the chest wall should be depressed 2 to 3 inches with each pressure application.

Repeat application of pressure about 60 to 80 times per minute. An assistant should be ventilating the subject's lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone you must concentrate on the massage until help can arrive.

Direct other assistants, when available, to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed.

Pause occasionally to determine if a spontaneous heart beat has returned.

As far as precautions are concerned, make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs. Since the heart cannot recover unless supplied with oxygenated blood, it is necessary to accompany cardiac massage with mouth-to-mouth artificial respiration.

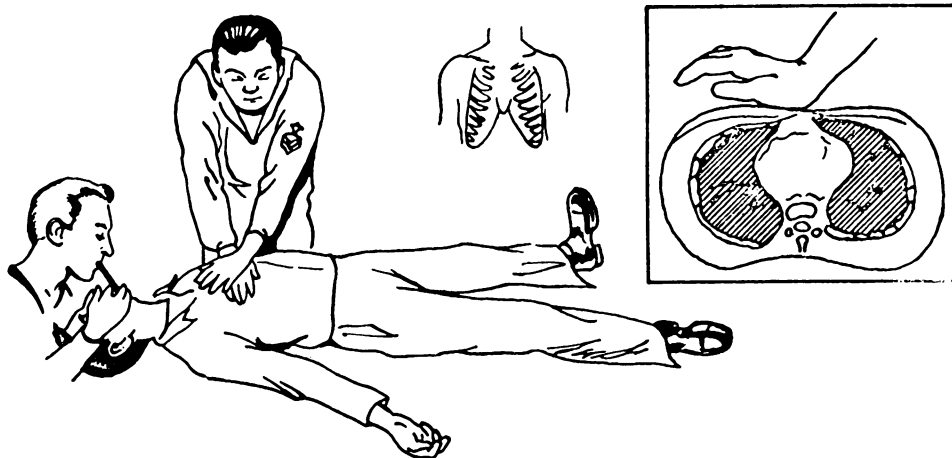


Figure 14-34.—Cardiac massage.

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When there is only one operator, the cardiac massage must be interrupted every half minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

If possible, ask the doctor or senior hospital corpsman to perform or observe a demonstration of these procedures to you and your men. Make sure that the men are told that the knowledge they acquire regarding this procedure and their ability to do so correctly may save their lives.

PRECAUTIONS WHEN HANDLING ELECTRON TUBES

As an Instrumentman, you will probably be required to observe safety precautions in handling, stowing, and disposing of radioactive cathode-ray, and fluorescent tubes.

The majority of accidents involving the use of electron tubes and components can be avoided by the use of standard electrical safety precautions. However, three specific areas which are known to be hazardous are worthwhile mentioning; the undischarged capacitor, the imploded cathode-ray tube, and the radioactive tube or component.

When electronic equipment is deenergized, high voltage capacitors maintain their charge for long periods of time. These components should in all maintenance application be shorted to ground by a device such as a Shorting Stick shown in figure 14-35.

The Cathode-ray tube (CRT) used in television applications and oscilloscopes which IC electricians use and maintain presents the unique problem of implosion. Extreme caution should be exercised when handling cathode-ray tubes. The glass envelope encloses a high vacuum, and because of the large surface area, the envelope is subjected to considerable force due to atmospheric pressure. The total force due to atmospheric pressure exerted on a 10-inch CRT, for example, is 3750 lbs or nearly 2 tons. Over 1000 lbs is exerted on the face alone.

To avoid serious injury, adequate precautions should be taken at all times to minimize the danger of breaking the glass envelope. Avoid scratching, striking, or using excessive force while handling the tube or when placing it in its deflecting yoke or in its socket. Never hold the tube by its neck and when setting the tube down always stand it on its face on a thick piece of felt, if available.

Before a CRT is discarded the tube should be rendered harmless by breaking the vacuum seal. This can be safely done by:

1. Placing the defective tube, face down, in any empty carton.
2. Carefully breaking off the locating pin from the tube. (See figure 14-36.)
3. Breaking off the tip of the glass vacuum seal with a small screwdriver or probe.

A word of caution regarding the phosphor with which the face of the CRT is coated. This gas is toxic and when disposing of a broken tube,

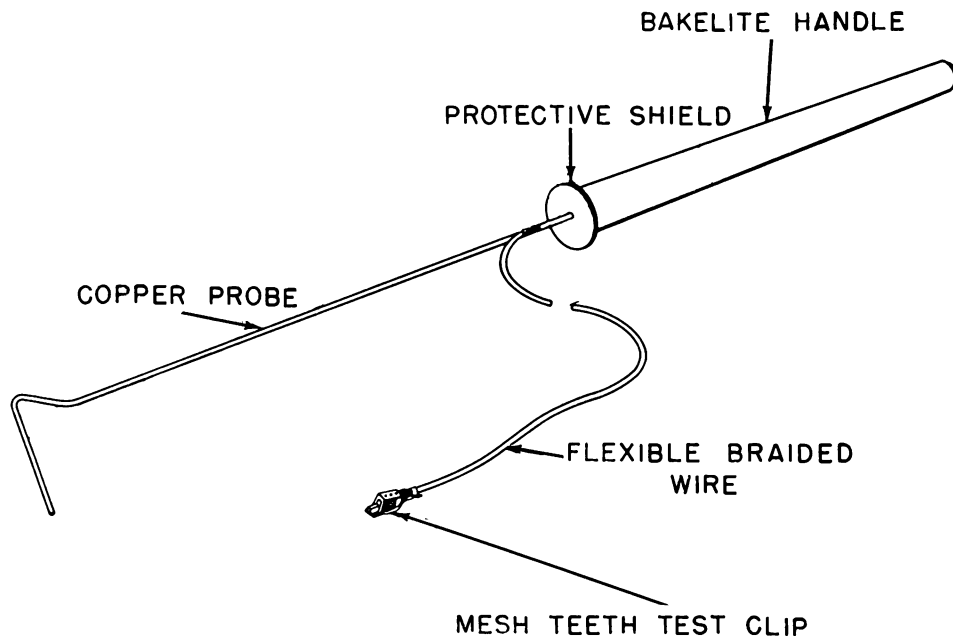


Figure 14-35.—Shorting stick.

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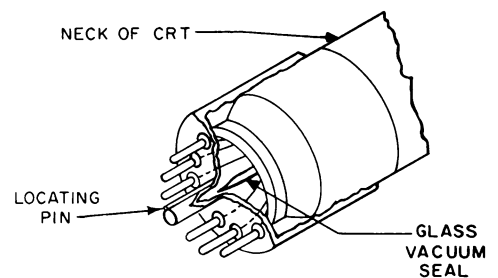
care must be exercised to avoid getting any of the compound on hands or into skin breaks.

In recent applications many manufacturers have found it worthwhile to install radioactive electron tubes. These tubes are known as tr, atr, spark-gap, glow-lamp, and cold-cathode tubes. Radioactive material is intentionally added to these tubes to produce a continuous supply of ionized particles. This ensures that the gas within the tube will always ionize at the same voltage. The principal radioactive materials in these tubes are Carbon 14, Cesium-Barium 137, Cobalt 60, Nickel 63, and Radium 226.

As long as a tube containing radioactive material is not broken, the hazard is slight. The concentration of radioactivity in a normal collection of electron tubes at maintenance shops does not approach a dangerous level, however, at major supply points, storage of large quantities of radioactive tubes a relatively small area may create a hazard.

A broken radioactive tube immediately becomes a hazard, since radioactive material deposited within a person's body produces internal radiation which may injure or destroy blood-forming organs and body tissue. The removal of this hazard is limited by the rate of excretion of the elements from the body and the natural

radioactive decay of the material. The degree of injury depends primarily on the quantity of radiation energy absorbed by the body cells. If only a small amount of radioactive material is absorbed, symptoms of internal injury may not appear for years. A current list of all radioactive tubes used in the Navy may be found in the Electronics Installation and Maintenance Book, Nav-Ships 0967,000,0130, Test Methods and Practices section, paragraph 1-15. Leading Petty Officers might find it profitable to check this list to ensure they are cognizant of which tubes they are currently using.



20.320(40)
Figure 14-36.—Construction of cathode-ray tube base.

The current combustion gas and smoke detector also uses radium—a radioactive material in its application, and equal care should be exercised when handling this component.

Certain specific precautions are required with the use of radioactive tubes and components to minimize the danger present.

1. Tubes and components should not be removed from their cartons until immediately before actual installation. This serves the function of both preventing breakage and preventing concentrations of several radioactive tubes in a small area.

2. When a unit is removed from equipment it should be placed in an appropriate carton to prevent possible breakage.

3. Tubes should never be carried in the pocket or elsewhere about one in such a manner that breakage might occur.

4. Extra care should be exercised while handling, installing, or removing tubes from equipment.

5. If breakage should occur, material contaminated by radioactivity should not be allowed to come in contact with any part of the body at any time. Care should be exercised to avoid breathing any vapor or dust (such as radon gas, a highly radioactive substance) which may be released by such breakage. Immediately locate all broken pieces and isolate the area until these pieces have been removed and the area found nonradioactive by testing with an adequate radiation-sensitive device.

6. No food or drink should be brought into a contaminated area or near any radioactive material.

7. Immediately after leaving a contaminated area, personnel who have handled contaminants in any way should remove contaminated clothing and wash contaminated areas of the body thoroughly with soap and water.

8. Should a wound be caused by sharp radioactive objects, mild bleeding should be stimulated by pressure about the wound and the use of suction bulbs. Do NOT suck the wound by mouth. Wash the wound with soap, and flush with plenty of clean water. If the wound is of a puncture type, or the opening is small, an incision should be made to promote free bleeding and facilitate cleaning and flushing the wound.

The disposal of items containing radioactive material is explained in Chapter 9670 of Naval Ships Technical Manual.

PRECAUTIONS IN USE OF ACIDS

If you must mix water and acid, **POUR THE ACID VERY SLOWLY INTO THE WATER. CAUTION:** If you pour water into acid, the MIXTURE WILL BOIL OVER QUICKLY AND BURN YOUR HANDS AND EVERYTHING IT TOUCHES.

Treat acid burns as quickly as possible. Wash the acid off with an abundance of water and then wash your hands under a spigot, if they were involved. Continue by neutralizing all acid which remains with limewater and raw linseed oil, or a paste of baking soda and water; **BAKING SODA IS A BASE AND IT NEUTRALIZES ACIDS.** If acid gets in your eyes, wash it out with cold water and then wash your eyes with weak lime water.

Wash alkali burns with plenty of cold water; then neutralize remaining portions of the alkali with vinegar or lemon juice. Remember that acids such as **VINEGAR** or **LEMON JUICE** neutralize bases (alkalies) such as lye.

PRECAUTIONS IN USE OF MERCURY

Mercury, which is an extremely toxic material and should be handled with great care, is much more volatile than one believes. It is very dangerous because its presence is not easily detected by the human senses. The vapor concentration at equilibrium and normal room temperature is 200 times the safe amount. Mercury is absorbed into the body in three ways: by inhalation of vapor, by ingestion from contaminated hands when eating or smoking, and by direct absorption through the skin when finely divided. (NOTE: It can be carried in the pockets, trouser cuffs, or shoes by which it may be carried to other places and may lodge in carpets or floor, thus creating a hazard at home.)

In handling mercury, the following precautions should be taken:

1. Store in a cool, well-ventilated area, in tightly closed, nonmetallic containers, plainly labeled; use "POISON" labels.

2. Remove rings, watches, and jewelry before handling mercury.

3. Exercise great care to avoid spilling.

4. Prohibit eating and smoking in or near the mercury handling area.

5. Wear protective clothing, and handle mercury only under the fume hood when in a laboratory.

6. Never leave mercury standing in open containers.

7. Pumps used to evacuate equipment containing mercury should discharge into the outside air, or into the fume hood in a laboratory.

8. The floor and bench tops in the mercury handling area should be as smooth and nonabsorbent as possible. Do not use metal edges on benches where mercury is handled.

PRECAUTIONS IN USE OF SOLVENTS AND CLEANERS

The technician who smokes while using a volatile flammable cleaning solvent is inviting disaster. Unfortunately, many such disasters have occurred. For this reason, the Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning purposes. Only non-volatile solvents shall be used to clean electrical or electronic apparatus.

In addition to the potential hazards of accidental fire, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged inhalation. The following list of "Don'ts" and "Dos" will serve as effective reminders to maintenance personnel who must use cleaning solvents.

DON'T

1. Don't work alone in a poorly ventilated compartment.
2. Don't breathe directly any of the vapor of a cleaning solvent for prolonged periods.
3. Don't spray cleaning solvents on electrical windings or insulation.
4. Don't apply solvents to warm or hot equipment, since this increases the toxicity hazard.
5. Don't use a solvent in the presence of any open flame, since this can lead to the formation of phosgene, a very poisonous gas.

DO

1. Do use a blower or canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.
2. Do open all usable port holes, and place wind scoops in them.
3. Do place a fire extinguisher close by ready for use.
4. Do use water compounds in lieu of other solvents wherever feasible.
5. Do wear rubber gloves to prevent direct contact.

6. Do use goggles when a solvent is being sprayed on permissible surfaces.

7. Do hold the nozzle close to the object being sprayed.

Inhibited methyl chloroform (1, 1, 1, trichloroethane) should be used where compounds are not feasible. Methyl chloroform is an effective cleaner and about as safe as can be expected when reasonable care is exercised. Its use requires plenty of ventilation and observance of fire precautions. Avoid direct inhalation of the vapor. Inhibited methyl chloroform is not safe for use with a gas mask since the vapor displaces oxygen in the air.

Methyl alcohol, chemically termed methanol, is also known as wood alcohol and wood spirit. It is used extensively as an industrial solvent, a duplicator fluid, "canned heat," a paint thinner, a degreaser, an antifreeze, and in the preparation of numerous laboratory products. Methyl alcohol is a pronounced fire and explosion hazard when exposed to heat and flame.

Ensure that care is taken to avoid breathing heavy concentrations of methyl alcohol vapors, and to prevent contact with the skin. Methyl alcohol should be used with caution, and only in open or well-ventilated spaces.

Freon 11, also known as MF, is inflammable, relatively nontoxic, and an excellent solvent for general laboratory use. Its vapors tend to exclude oxygen, however, and it should not be used for prolonged periods without adequate ventilation.

Carbon tetrachloride, although inflammable, is highly toxic and its use is prohibited. Trichloroethylene (ethylene trichloride), also inflammable, is somewhat less toxic, and may be used with caution. It should always be used under the fume hood (in the laboratory) and stored in tightly closed containers bearing a "POISON" label. Keep the work area clean, and wash the hands thoroughly after using.

For additional information on the safety precautions to be observed when using solvents, see articles 9600-412 through 9600-415 of the Navy Ships Technical Manual.

PRECAUTIONS IN CONNECTION WITH GAS SYSTEMS

Compressed air should always be used with great care. Never direct a stream of air at yourself or any other person. Air must never be used for cleaning chassis or benches; aside from filling the air with dust, particles may be blown

into equipment or your face. Use a vacuum cleaner for such cleaning.

Always wear protective goggles when handling air over 150 psi. It is advisable to use eye protection for lower pressures under certain conditions.

Oil in contact with compressed air constitutes a highly dangerous explosive hazard. In the construction, repair, or maintenance of compressed air systems, great care must be exercised to keep oil out of tanks, lines, gages, and valves.

Bottles containing compressed gas should be handled carefully. The precautions for use of compressed air should be observed and, in addition, bottles must be stored in an upright position and secured against toppling over. Oxygen is especially dangerous; any oil on valves, gages, or fittings constitutes an explosion hazard.

When handling any liquified gas (liquid nitrogen and liquid oxygen), safety glasses and protective clothing should be worn. Special containers are used, and all instructions concerning these containers should be followed; especially in the case of liquid oxygen, where the presence of grease, oil, or contamination constitutes an explosion hazard.

Care must be taken to avoid high concentrations of carbon dioxide in confined spaces, as there is danger of suffocation to personnel unless special apparatus is available. In electrical fires,

remember that quick action is most needed for deenergizing the circuit. When this has been done, stop, look, and think, and then act fast to extinguish the fire before it spreads.

Carbon dioxide is the preferred fire extinguisher for use on electrical fires. It is a non-corrosive gas which does not damage cables or equipment. It is nonconducting, and the stream of carbon dioxide from an extinguisher can be directed against energized circuits without danger of shock.

Extreme care must be used in fresh or salt water or foam is directed at an energized circuit since all of these can conduct current and shock firefighters. In addition, equipment damaged by salt water or foam is more difficult to recondition than if carbon dioxide had been used. Consequently, while water or foam may have to be used to prevent a disastrous fire, it is decidedly advantageous and preferable to use carbon dioxide alone.

Solidified carbon dioxide (dry ice) should be used only in a well-ventilated room. Large dry ice storage containers are a hazard because the heavy CO₂ gas collects on the bottom and there is danger of suffocation. In handling dry ice, heavy gloves should be worn to avoid frostbite. Whenever a saw or hammer is used to break up the large ice blocks, safety goggles should be worn.

CHAPTER 15

TYPEWRITERS

Typewriters are used extensively in various offices aboard ship; and the instrument shop is responsible for their repair and maintenance. Before you can qualify for advancement to IM3, you must be able to remove and clean rubber parts, disassemble, clean, inspect, replace faulty parts, reassemble, lubricate, and adjust manual typewriters. You must also know how to analyze and remedy casualties as well as overhaul manual typewriters.

The word OVERHAUL means to check thoroughly for and make necessary repairs and adjustments to a machine, including the replacement of parts. When a mechanic, for example, says he overhauled a motor or a typewriter, he means that he disassembled the machine, cleaned and inspected parts, replaced defective or broken parts with new ones, reassembled, oiled, and adjusted the machine until it ran to his liking. In other words, he put the machine in practically new working condition, exactly as required when overhauling a typewriter.

Because of the amount of material required to cover an overhaul job on a typewriter, space in this text does not permit a discussion of the procedure for all makes and models. The only thing that can be done, therefore, is to discuss the procedure for overhauling one make of standard typewriter (with references to major differences in other makes and models) and refer you to other manufacturers' technical manuals for differences in procedure for overhauling their machines. The mechanisms of standard typewriters are similar, but there are some differences which you should know.

Figure 15-1 shows a Royal standard typewriter with the top cover removed, and with the nomenclature of visible parts listed. When you finish studying this illustration, refer to figure 15-2 which gives a front view of a standard Smith-Corona typewriter, with some of the nomenclature listed. Compare the nomenclature

of this machine with the Royal, and also note the differences in the location of various parts.

In addition to information concerning manual typewriters, you must also know the nomenclature, function of parts, tools, and definitions of terms associated with the repair of electric typewriters as well as other office machinery. Therefore, electric typewriters are also discussed later in this chapter.

REMINGTON STANDARD TYPEWRITER

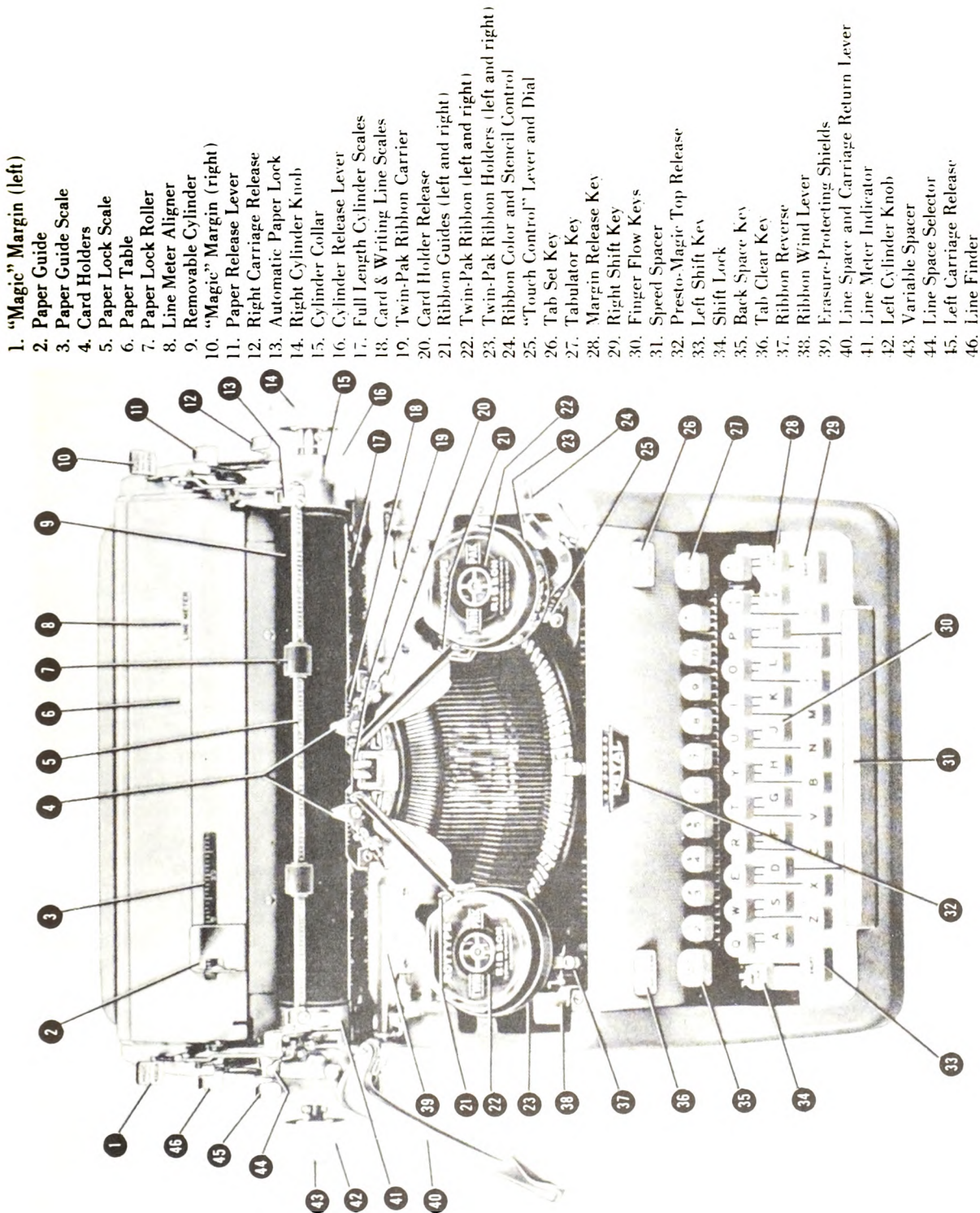
The following discussion covers the overhaul and repair of a Remington standard typewriter. Although the Remington Model 24 is widely used, the principle of operation of the standard manual typewriter illustrated is the same. The major difference is the case and some nomenclature. Emphasis in this chapter is placed on the operation of different mechanisms and parts in the Remington machine, analyzing troubles, effecting repairs, and making adjustments.

PARTS AND MECHANISMS

The different mechanisms and parts are discussed first, so that you will understand what they are and where they fit when disassembly is considered, and also when you make repairs and adjustments.

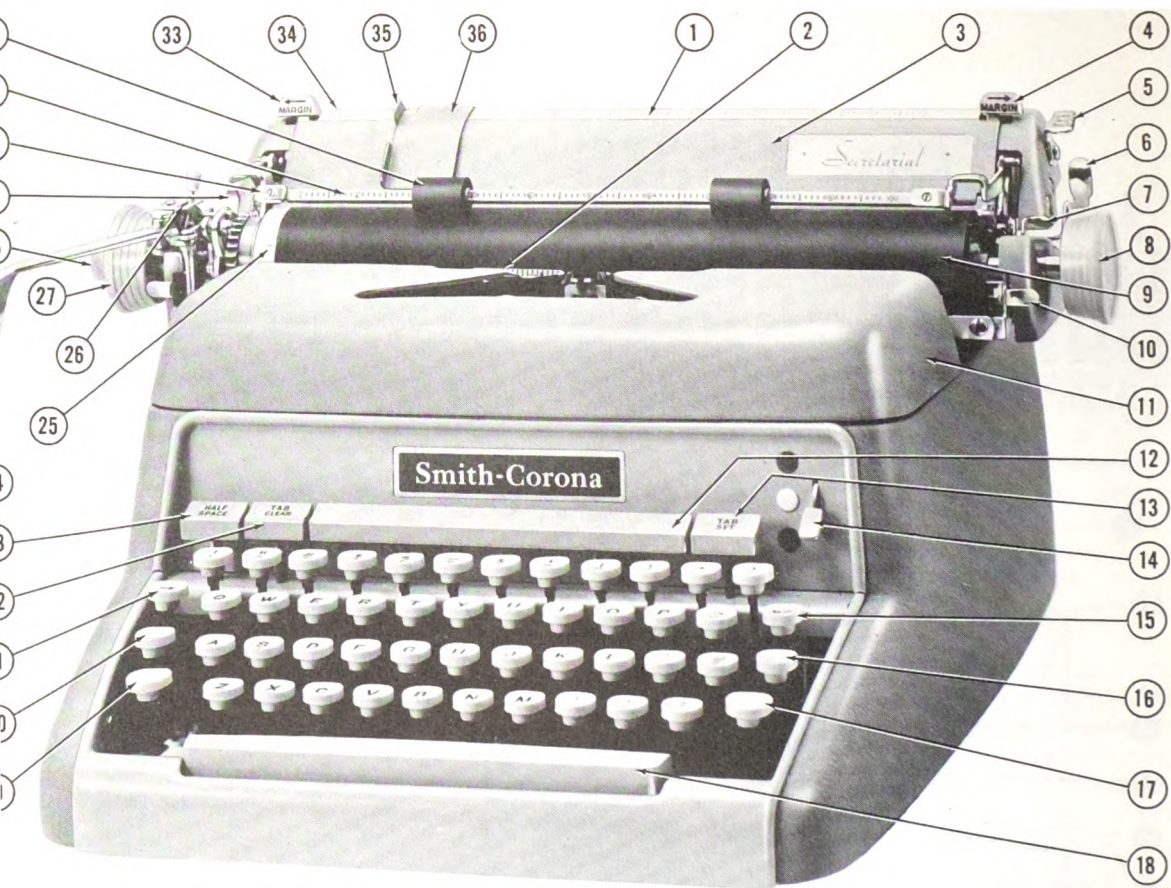
Type Bar Mechanism

If you know the nomenclature of important parts in a mechanism, and all mechanisms in a typewriter, you can follow the action of the parts better, and develop a better understanding of the role they play in the operation of the machine. Keep this thought in mind as you study the type bar mechanism illustrated in figure 15-3, and do the same thing when you study all



61. 37X

Figure 15-1. —Royal standard typewriter.



per guide scale
 ten scale
 per table
 ight margin button
 tal tab clear lever
 per release lever
 ight carriage
 release
 ight platen knob
 movable platen
 ight platen latch
 on spool cover
 ulator bar
 ulator set key

14. Ribbon color control
 15. Margin release key
 16. Right shift lock
 17. Right shift key
 18. Full-size space bar
 19. Left shift key
 20. Left shift lock
 21. Back space key
 22. Tabulator clear key
 23. Half space (error control)
 24. Carriage return lever
 25. Page gage
 26. Line space regulator

27. Left platen knob
 28. Variable line spacer
 29. Line retainer
 30. Three-position floating paper bail
 31. Paper bail scale
 32. Paper bail roll
 33. Left margin button
 34. Automatic centering 11-inch sheet
 35. Automatic centering 8 1/2-inch sheet
 36. Adjustable paper guide

Figure 15-2.—Smith-Corona standard typewriter.

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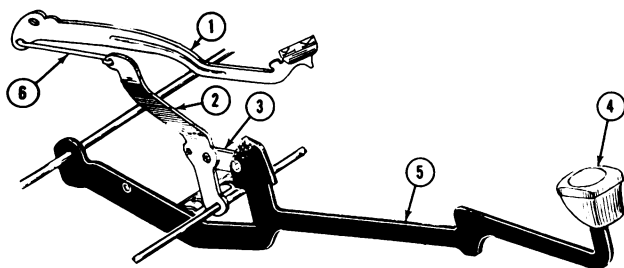
other mechanisms. Learn the nomenclature as you study each illustration.

When a typist strikes a key top, the key-lever to which it is secured moves downward and pulls the type bar bellcrank link forward and down. As the type bar bellcrank link moves forward, it pulls the type bar bellcrank top forward, and also the type bar bellcrank link attached to it. The type bar bellcrank link, connected with the type bar at its base, pivots the type bar on the fulcrum wire and swings it up and to the rear. This, in essence, is how the type bar mechanism functions.

Escapement Mechanism

The escapement mechanism consists of an escapement wheel (fig. 15-4) to which a pinion is attached; an escapement rocker body, containing the escapement loose dog and the rigid dog; and the escapement operating bail, with link and type bar universal bar (U-bar). The escapement loose dog can move laterally and vertically. An arm controls the amount of lateral travel, and the loose dog guide controls the amount of vertical travel. A spring holds the loose dog against the upper arm of the loose dog guide and to the right (facing the rear part of the machine) when it is not in contact with a tooth of the star wheel.

When the escapement mechanism is in its normal position, the escapement loose dog is in contact with a tooth of the escapement wheel which (by the meshing of its pinion wheel with the feed rack) prevents the carriage from moving.



- | | |
|----------------------------|--------------------------|
| 1. Type bar | 4. Key top |
| 2. Type bar bellcrank | 5. Key lever |
| 3. Type bar bellcrank link | 6. Type bar connect-link |

61.40X

Figure 15-3.—Type bar mechanism.

When a type bar travels toward the platen (top rearward), the heel of the type bar contacts the U-bar which then pivots on the type bar U-bar oscillator (fig. 15-4). The type bar U-bar pivots on the type bar U-bar oscillator bracket and causes the tail of the type bar U-bar to move rearward and pivot the operating bail and roll. The operating bail then pulls the escapement trip wire forward and rocks (pivots) the escapement rocker top rearward. This action disengages the loose dog from the star wheel tooth and allows the star wheel to advance until the tooth just released is intercepted by the rigid dog. When the escape wheel moves, the tension on the carriage spring moves the carriage to the left until the tooth of the wheel is caught and held by the rigid dog. As the type bar returns to its normal position, it restores the entire mechanism to its normal rest position.

Spacebar Mechanism

When the spacebar is depressed, the spacebar levers (fig. 15-5) move down and pivot the spacebar shaft toward the front of the machine, causing the rear end of the friction-fitted extension arm to move upward. As the rear end of the extension arm rises, it lifts the U-shaped connecting link, which raises the spacebar push link. The roll at the top of this link then contacts the escapement arm and rocks the escapement rocker top rearward. This action disengages the loose dog and allows the star wheel to advance to complete the escapement action.

When the spacebar is released, the spring attached to the top of the U-shaped connecting link over the rear end of the extension arm on the spacebar shaft returns the spacebar mechanism to its rest position.

Linelock and Margin Release Mechanism

Study the linelock and margin release mechanism illustrated in figure 15-6, and refer to it as you study its operation.

As the finger of the right margin stop moves to the left, it contacts the margin stop release blade and moves it to the left. This action pivots the operating lever left and moves the linelock bellcrank to the right. The upper extension of the linelock U-bar is then pulled forward by the spring connected to the right end. This action pushes the linelock push bar to the rear and moves the lip on the rear of the

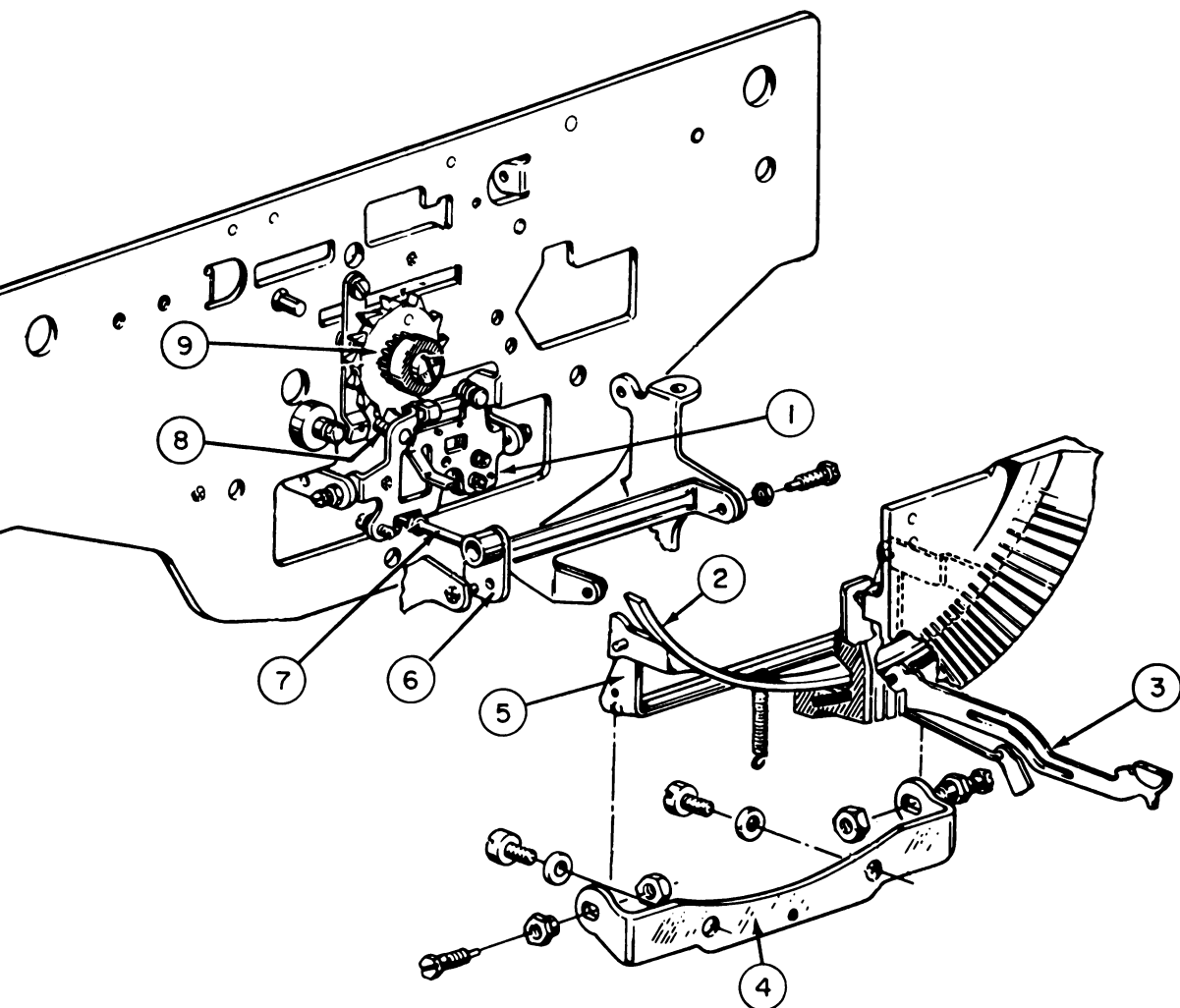
lock U-bar under the upper extension of the levers to lock the keyboard. This is the locking point.

When the margin release key is depressed, the margin release keylever swings down and raises the margin release keylever arm extension. This action lifts the margin release push

link, which pivots the front of the margin stop release blade down to allow the right margin stop to pass to the left.

Backspace Mechanism

As the backspace key is depressed, the backspace keylever roll on the opposite end raises



1. Escapement rocker
2. Type bar universal bar
3. Type bar
4. Type bar universal bar oscillator bracket

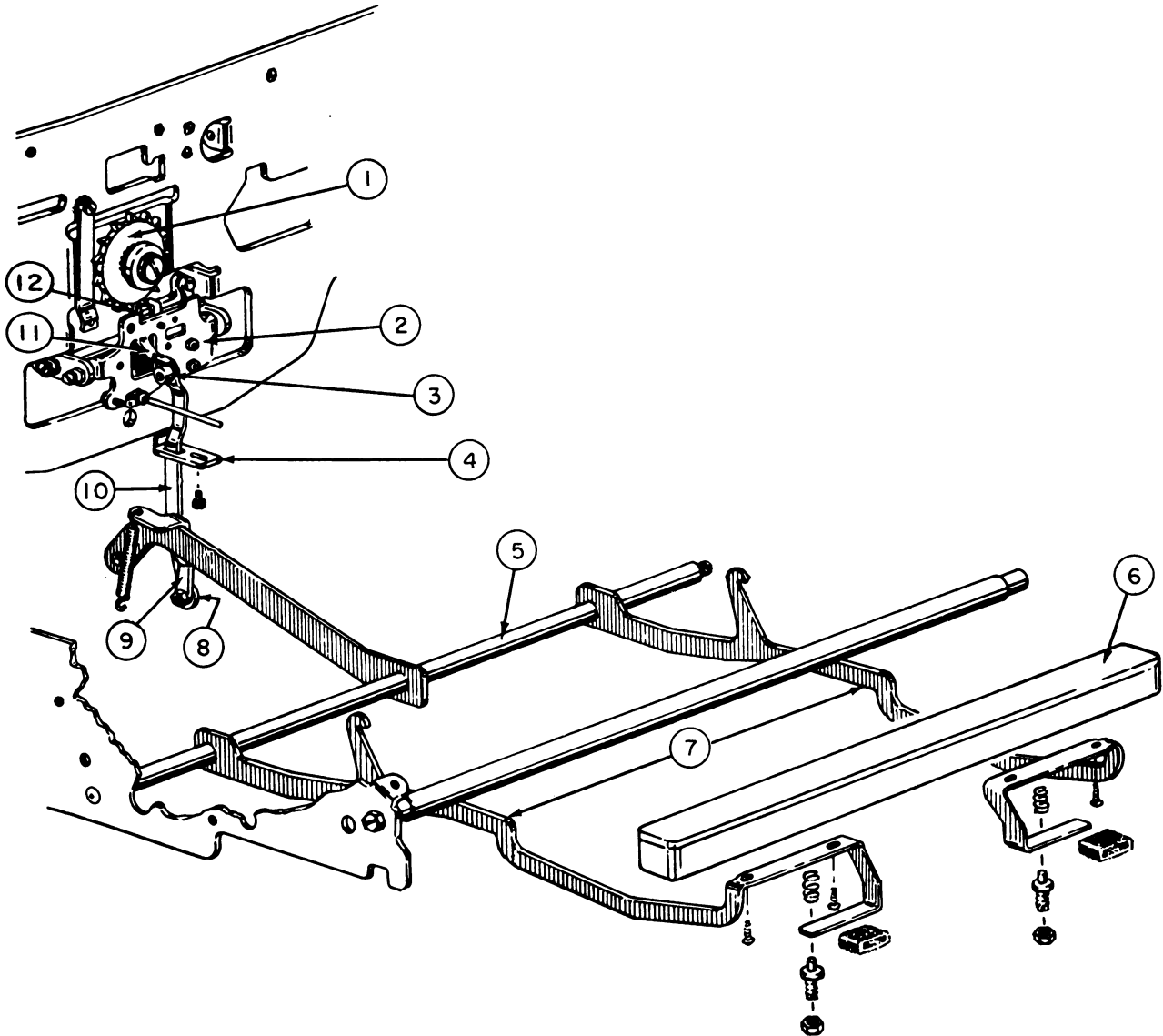
5. Type bar universal bar oscillator
6. Operating bail (roll)
7. Escapement trip pull wire
8. Loose dog
9. Escapement wheel (star wheel)

Figure 15-4.—Escapement mechanism (manual typewriter).

61.39X

the front end of the backspace lever arm. See figure 15-7. When the front of the backspace

lever arm moves up, the arm pivots and its back end pushes the end of the backspace pawl



1. Escapement wheel (star wheel)
2. Escapement rocker
3. Spacebar push link roll
4. Spacebar push link adjusting guide
5. Spacebar shaft and extension arm

6. Spacebar
7. Spacebar levers
8. Spacebar push link eccentric
9. U-shaped connecting link
10. Spacebar push link
11. Escapement rocker arm
12. Loose dog

Figure 15-5.—Spacebar mechanism (manual typewriter).

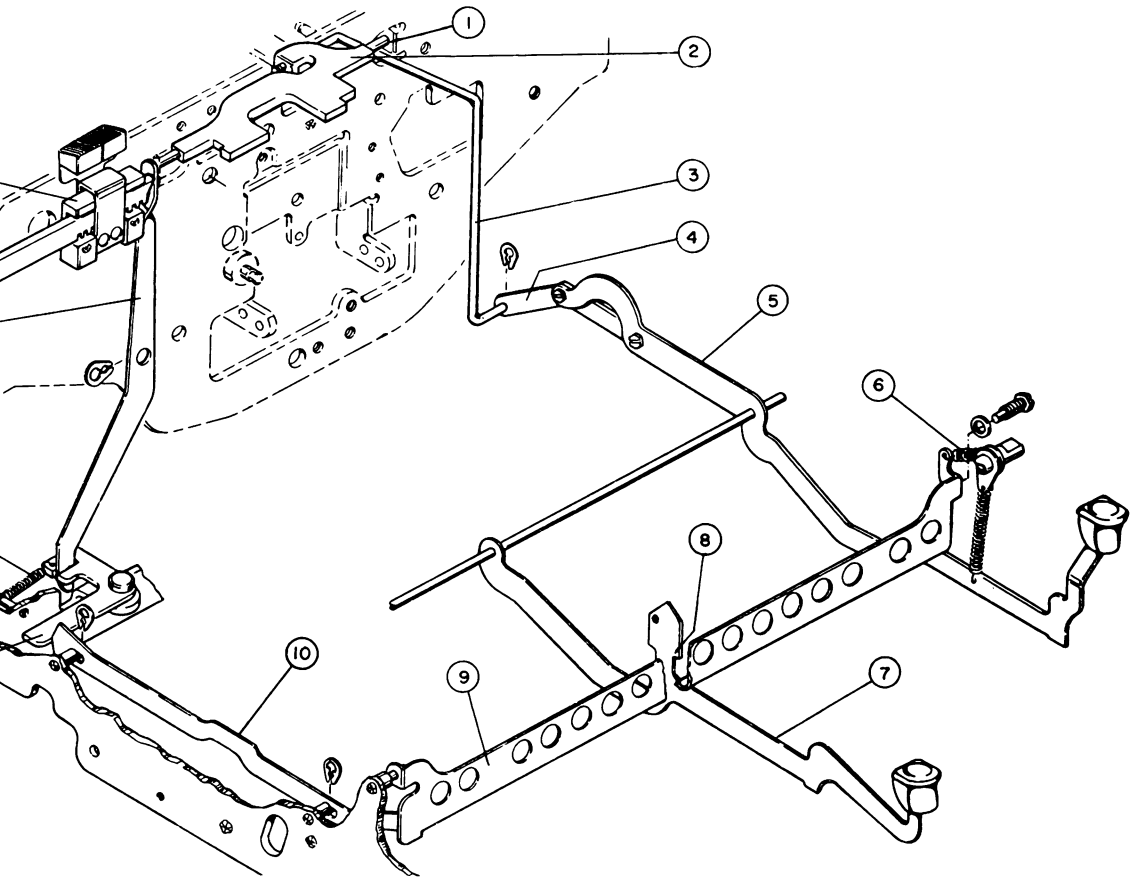
91.3X

lever on which it rests down. The tip of the backspace pawl actuating lever engages a tooth of the star wheel and moves it one full space.

Section Mechanism

When a typist moves the ribbon control lever (15-8) to a certain position, the ribbon control lever moves the ribbon control shaft arm forward or backward, in accordance with the

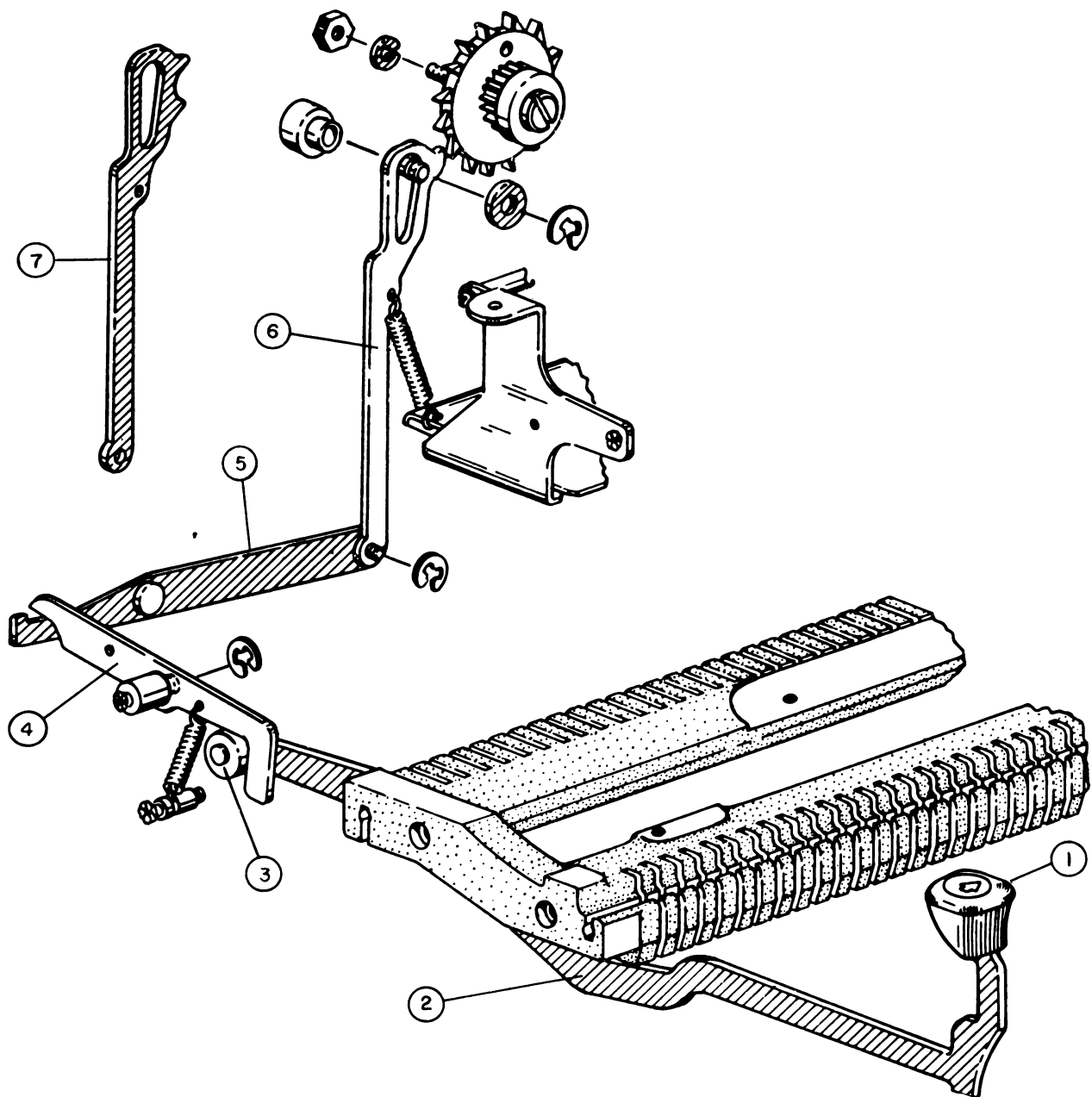
position of the control lever. As the ribbon control shaft arm moves, it carries the ribbon control shaft along, and the top of the ribbon control shaft control arm is also moved to the front, or to the rear. The top of the ribbon lifter push link is then positioned to the front or to the rear. (The ribbon lifter push link stud moves in a T-shaped slot of the ribbon actuator arm to one of four positions, and the position in the slot varies the amount of upward travel of the ribbon actuator arm.)



- | | |
|--|-------------------------------|
| 1. CONTACT POINT OF RIGHT MARGIN STOP | 8. LOCKING POINT |
| 2. MARGIN STOP RELEASE BLADE | 9. LINELOCK U-BAR SPRING |
| 3. MARGIN PUSH RELEASE LINK | 10. LINELOCK PUSH BAR |
| 4. MARGIN RELEASE KEYLEVER ARM EXTENSION | 11. LINELOCK BELLCRANK |
| 5. MARGIN RELEASE KEY LEVER | 12. LINELOCK RESTORING SPRING |
| 6. LINELOCK RESTORING SPRING | 13. OPERATING LEVER |
| 7. KEY LEVER | 14. LEFT MARGIN STOP |

Figure 15-6.—Linelock and margin release mechanism.

61.48X



- | | |
|-----------------------------|-------------------|
| 1. Backspace key | 5. Backspace pawl |
| 2. Backspace key lever | actuating lever |
| 3. Backspace key lever roll | 6. Pica pawl |
| 4. Backspace lever arm | 7. Elite pawl |

61.43X

Figure 15-7.—Backspace mechanism (manual typewriter).

ribbon covers, the actuator arm is in one of four positions: red, black, blue, or stencil. The ribbon guide is then moved to carry the ribbon to one of three positions.

Mechanism

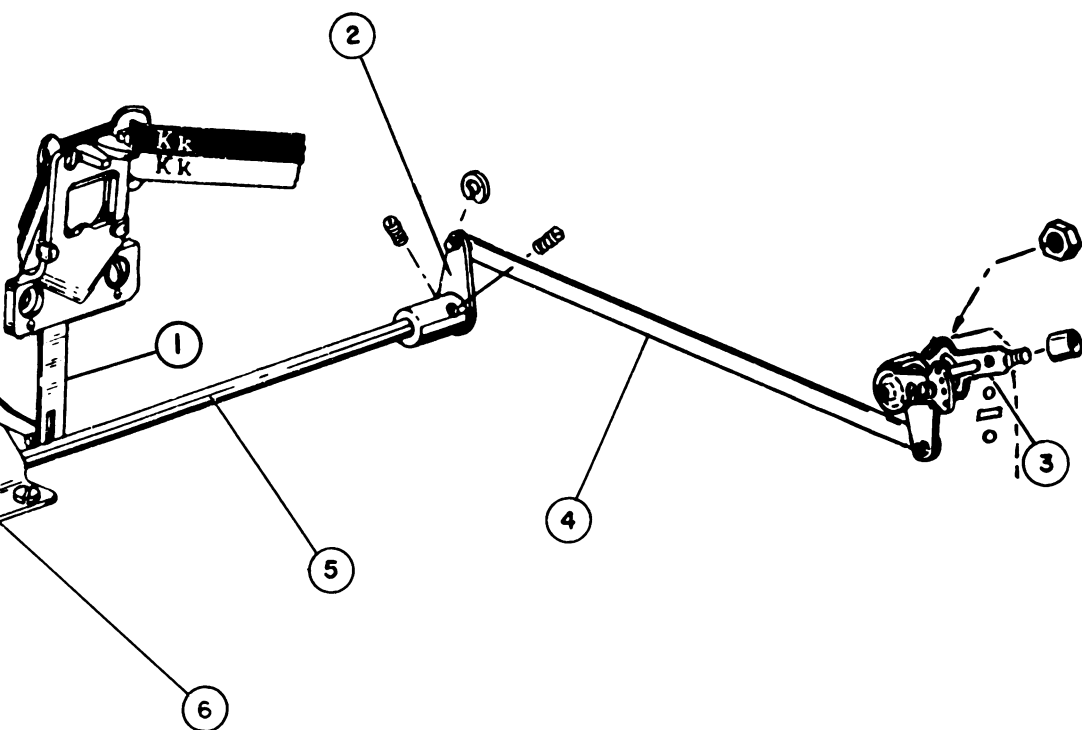
When the lever is depressed, it also depresses the front of the ribbon universal bar. This action raises the ribbon lift

assembly, or toggle link is rigidly connected to the bottom of the ribbon U-bar. The eccentric adjusts the height of the ribbon U-bar.) When the ribbon U-bar toggle link rises, it raises the lift bellcrank assembly, which

pushes the ribbon lifter push link up. The front of the ribbon actuator arm is then raised, and the ribbon guide and ribbon are raised to cover the type. (The ribbon lifter push link stud contacts the black upstop screw and limits upward travel in the BLACK position. The ribbon actuator arm contacts the ribbon actuator arm stop and limits upward travel in the RED position.)

Ribbon Feed and Reverse Mechanism

Refer to figure 15-10 as you study the operation of the ribbon feed and ribbon reverse mechanism. Note the pinion on the spring drum pinion shaft. This pinion meshes with a gear connected to the spring drum. Some typewriters use a different system for operating the ribbon-



- | | |
|-----------------------------|-------------------------------------|
| 1. Ribbon guide | 6. Ribbon actuator arm bracket |
| 2. Ribbon shaft control arm | 7. Ribbon lifter push link |
| 3. Ribbon control lever | 8. Ribbon control shaft control arm |
| 4. Ribbon control link | 9. Ribbon actuator arm (T-slot) |
| 5. Ribbon control shaft | |

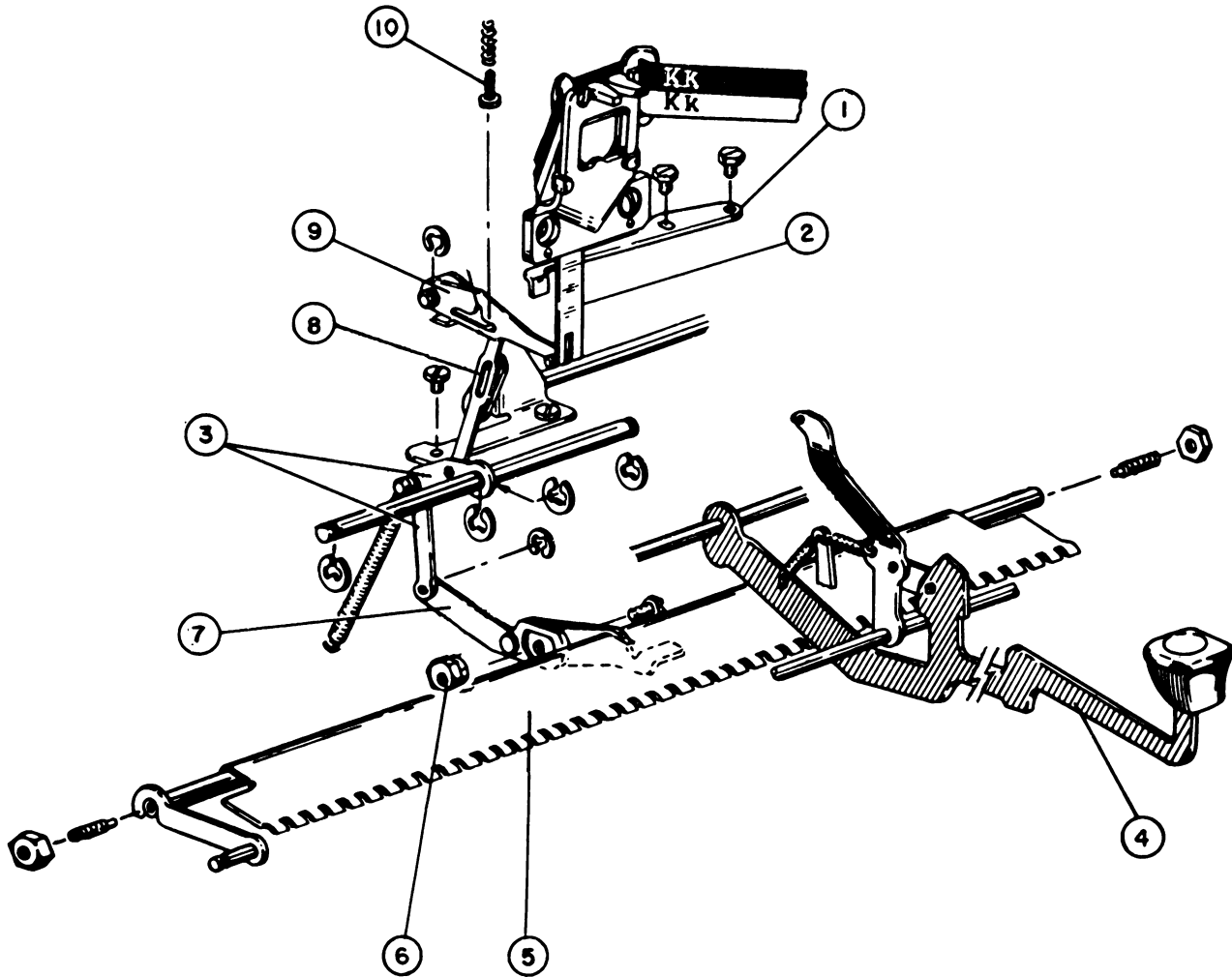
Figure 15-8.—Ribbon selection mechanism.

61.42X

movement of carriage, with appropriate chain and gear attached, pawl feed, and so forth.

As the carriage moves from right to left, the spring drum gear (meshed with the spring drum pinion on the spring drum pinion shaft) turns the spring drum pinion in the direction indicated by the arrow (fig. 15-10). The ribbon

drive gear pinion meshes with the ribbon drive gear and drives the top of the ribbon drive gear forward. The ribbon drive gear stud engaged with the ribbon drive shaft arm turns the ribbon drive shaft top forward. The right ribbon driving gear is meshed with the ribbon spool shaft pinion and turns the right ribbon spool shaft

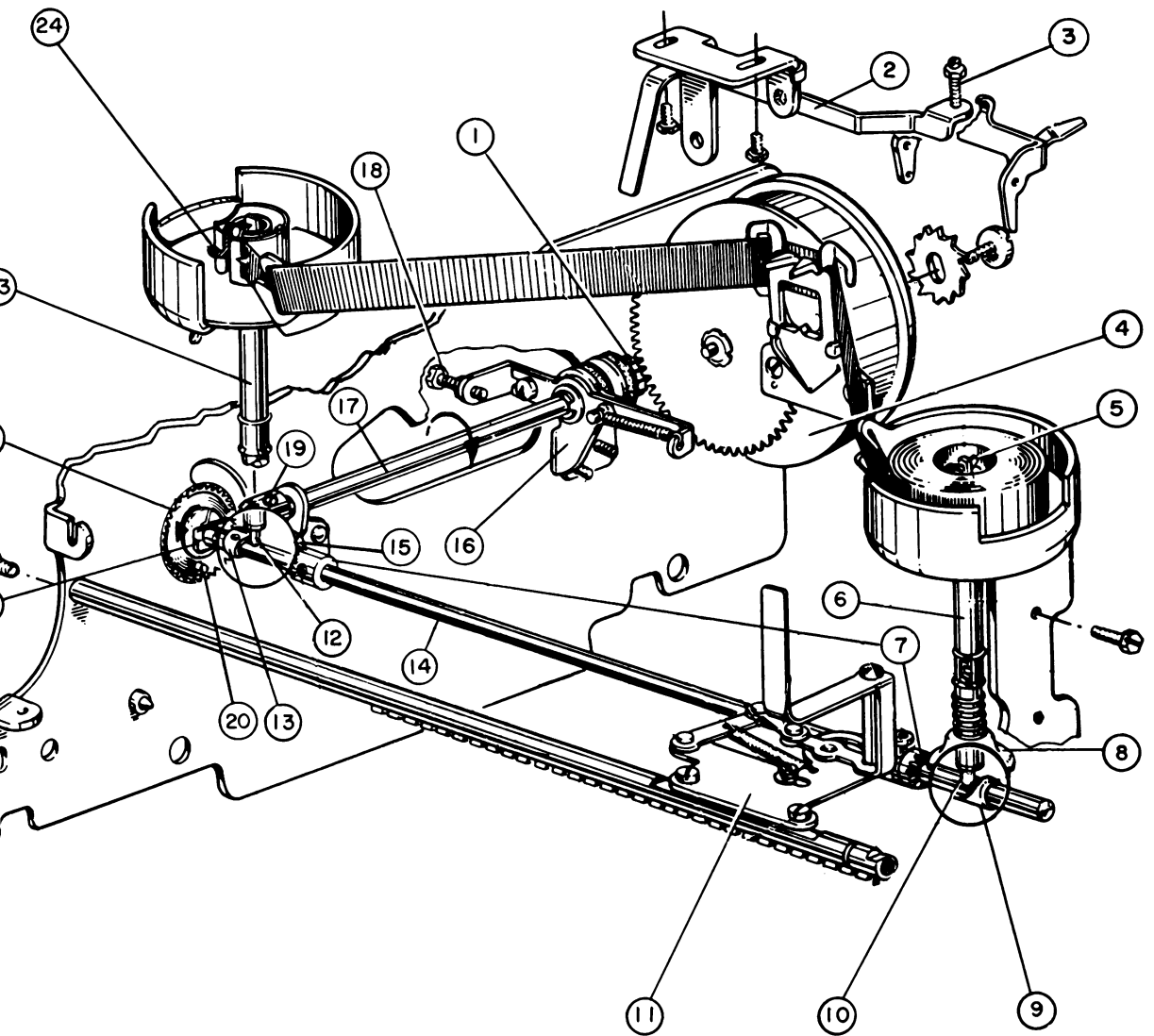


1. RIBBON ACTUATOR ARM STOP
2. RIBBON GUIDE
3. RIBBON LIFT BELLCRANK ASSEMBLY
4. KEYLEVER
5. RIBBON UNIVERSAL BAR (*U-bar*)

6. RIBBON U-BAR ECCENTRIC
7. RIBBON LIFT ASSEMBLY
8. RIBBON LIFTER PUSH LINK
9. RIBBON ACTUATOR ARM
10. BLACK UPSTOP SCREW

Figure 15-9.—Ribbon cover mechanism.

61.42X



- | | |
|---|--|
| 1. Ball clutch pinion | 13. Ribbon reverse cam (left & right) |
| 2. Pinion release bellcrank | 14. Ribbon drive shaft |
| 3. Ribbon throwout screw | 15. Ribbon spool shift pinion (left & right) |
| 4. Spring drum | 16. Spring drum pinion support bracket |
| 5. Reverse trigger (left & right) | 17. Spring drum pinion shaft |
| 6. Ribbon spool shaft (left & right) | 18. Ball clutch pinion adjusting screw |
| 7. Ribbon driving gear (left & right) | 19. Ribbon drive gear pinion |
| 8. Ribbon spool shaft pinion | 20. Ribbon drive gear stud. |
| 9. Ribbon reverse cam (left & right) | 21. Ribbon drive shaft arm |
| 10. Ribbon reverse plunger (left & right) | 22. Ribbon drive gear |
| 11. Ribbon reverse detent plate | 23. Ribbon spool shaft (left & right) |
| 12. Reverse plunger (left and right) | 24. Reverse trigger (left & right) |

Figure 15-10.—Ribbon feed and reverse mechanism.

61.41X

counterclockwise, winding the ribbon onto the right spool.

When the ribbon is all wound on the right spool and the left spool is empty, the left reverse trigger is released and the left reverse plunger drops down into the path of the left ribbon reverse cam, which forces the ribbon drive shaft to the left. The toggle on the ribbon reverse detent plate breaks to lock the ribbon drive shaft to the left. (NOTE: See spring and toggle in illustration.) The ribbon then starts to reverse (left gears meshed) and to feed onto the left spool. As the ribbon starts to wind onto the spool, it presses the reverse trigger down and raises the left reverse plunger up, out of the way of the left ribbon reverse cam.

An important feature of this mechanism is the ball clutch (connected to the spring drum pinion) which allows the carriage to return without rotating the spring drum pinion shaft. In other words, the ribbon does not move when the carriage is moved left to right. When the right end of the pinion release bellcrank is depressed, the left end disengages the spring drum pinion from the spring drum (tab or carriage release action).

Tabulator Mechanism

When the tab bar is depressed, the tab connecting link moves to the rear and the tab bellcrank adjusting screw moves up with the rear of the tabbell crank. Study figure 15-11. The tab bellcrank adjusting screw contacts the tab stop blade and raises it up. The lip on the front of the tab stop blade then raises the front of the friction bail. The friction bail pivots on its fulcrum, and the lower extension of the friction bail pushes the lower extension of the escapement loose dog release bail forward. The friction bail toggle, in turn, breaks to allow the friction screw arm to move forward to slow the carriage down (friction type brake). The escapement loose dog release lip then depresses the loose dog and allows the star wheel to rotate. The ribbon throwout screw goes down with the rear of the escapement loose dog release bail. The escapement loose dog restores before the tab blade drops clear of the SET tabstop, which prevents the carriage from traveling beyond the desired position.

Key Tension Mechanism

The mechanism which controls key tension is illustrated in figure 15-12.

Key tension (key touch) is regulated by the amount of spring tension applied to the type bar bell cranks. Refer to part A of figure 15-12, which shows the key tension regulator lever in the UP position and the key tension slide to the front of the machine. Note the slanting position of the slots in the key tension slide. When the slide is pushed to the front of the machine, it moves a little to the left. While the slide is in the front position, the keylever spring is allowed full play and the **LIGHTEST** key tension is obtained.

If the key tension regulator lever is in the DOWN position, as illustrated in part B of figure 15-12, the key tension slide is in the BACK position and the key lever spring and bellcrank are inoperative; but the bellcrank spring can operate to increase key tension to its greatest amount.

DISASSEMBLY

You will normally disassemble a typewriter to the extent necessary to comply with the requirement of the work request. The first thing to do when you get a typewriter in the shop is to **CHECK IT OUT** to locate troubles which adversely affect its operation. The next step is disassembly to the extent necessary to locate trouble(s), or complete disassembly if the work request states **OVERHAUL AND REPAIR**. All data obtained during partial or complete disassembly should be recorded for entrance on the casualty analysis report.

The procedure for disassembling a Remington standard typewriter is given next in sequential order. The part to be removed is listed first, followed by a brief description of the steps to follow in removing it.

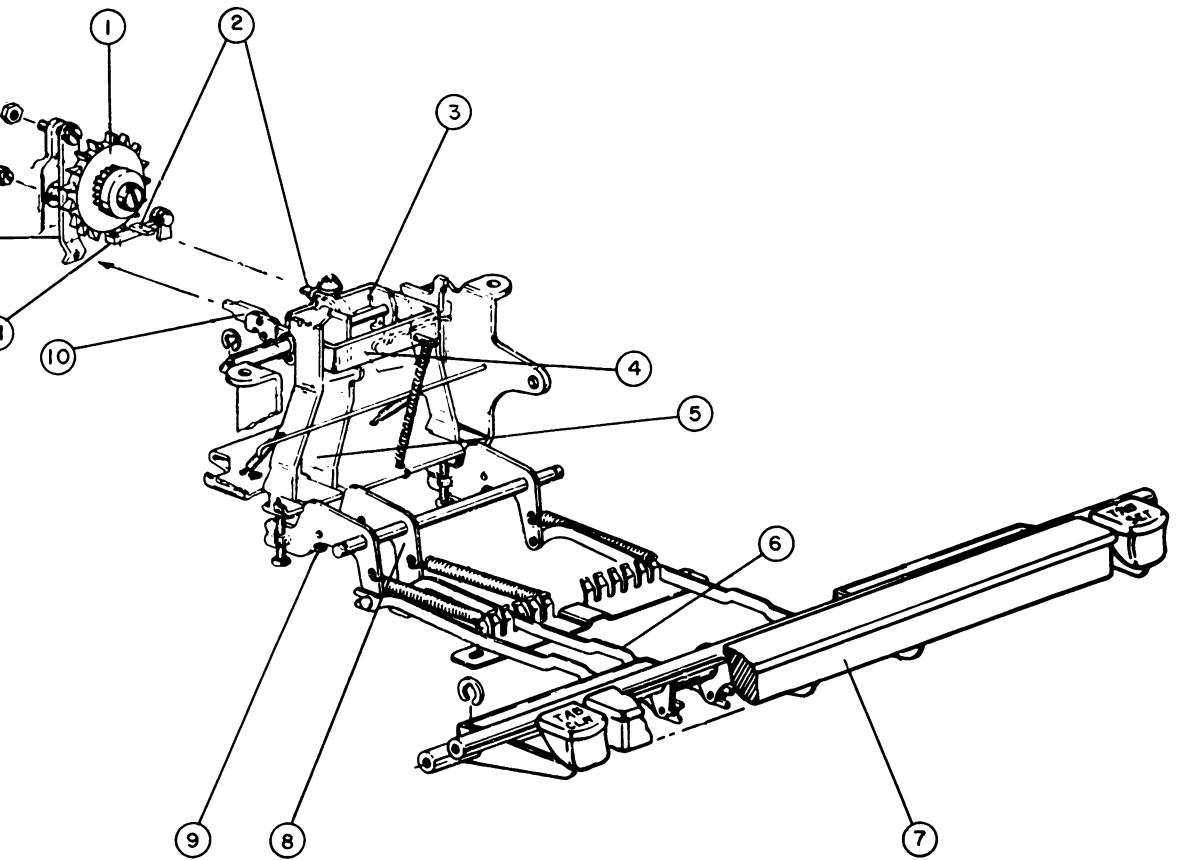
1. Top cover.—With the machine facing you, pull straight up on the cover.

2. Ribbon winding disk, ribbon, and ring.—Disconnect the ribbon from the ribbon guide and wind all of it on the spool containing the ribbon ring. Then remove the winding disk from the unwound spool and disconnect the end of the

attached to it. Wind all of the ribbon to spool; then remove the winding disk, and spool.

rear panel.—Remove two mounting screws, slightly raise the rear of the panel, and panel rearward.

4. Side panels.—Remove front, rear, and top mounting screws and raise the rear of the panel to remove it from the base mounting stud. Then slide the panel from the front stud and lower it enough to free it from the ribbon selector or touch control lever.



Star wheel
Escapement loose dog release lip
Escapement loose dog release bail
Friction bail
Tabulator stop blade
Tab connecting link
Tabulator bar (TAB BAR)

8. Tab bellcrank
9. Tab bellcrank adjusting screw
10. Friction bail toggle
11. Loose dog
12. Friction screw arm
13. Tabulator friction spring
adjusting screw

Figure 15-11.—Tabulator mechanism (manual typewriter).

61.44X

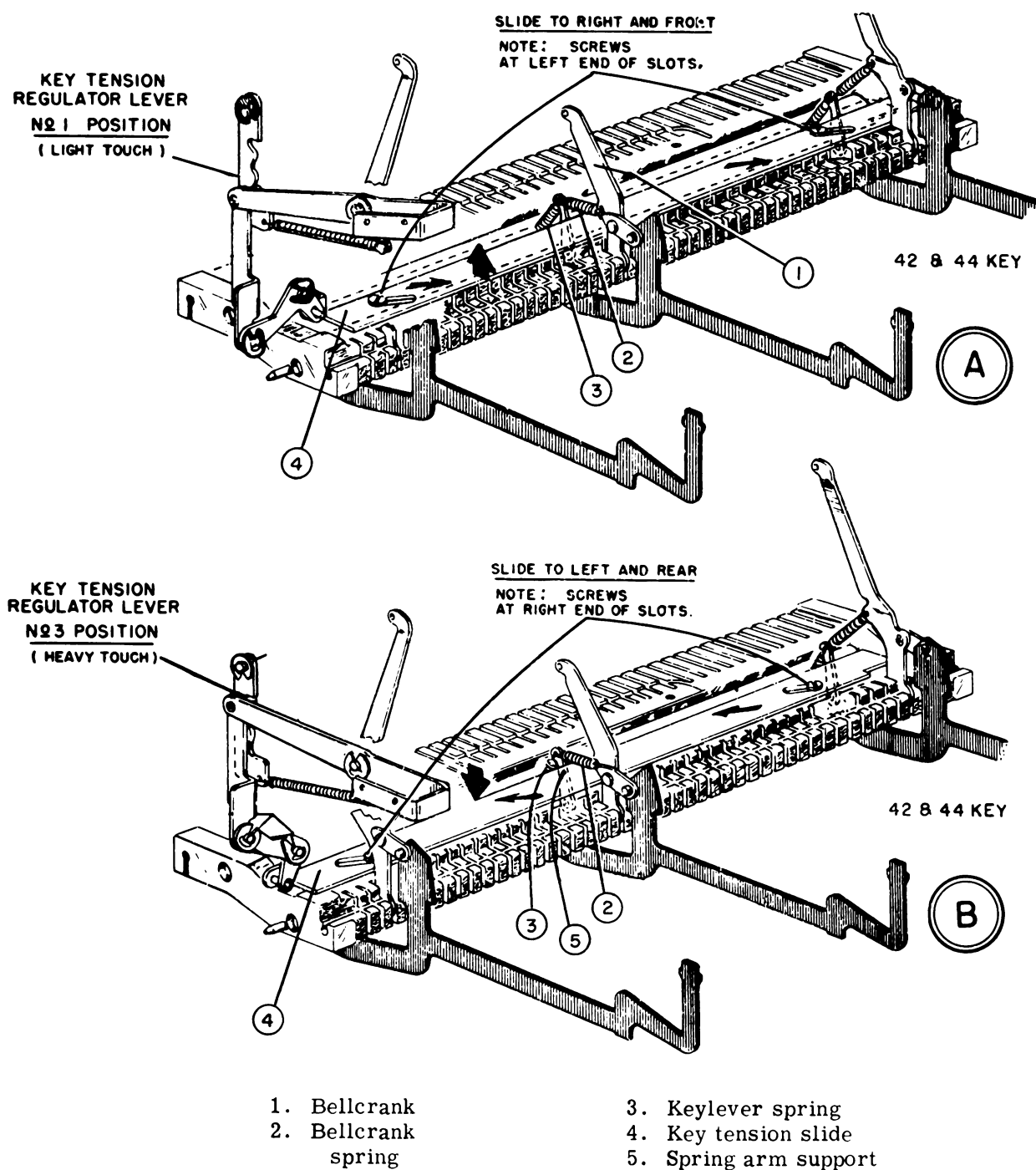


Figure 15-12.—Key tension mechanism.

91.4X

5. Front panel.—Release the mounting nuts at the rear of the front panel about 1/4 turn. Then loosen the screws which hold the upper front end of the side panels and remove the front panel.

6. Base.—Remove the mounting screws. (Do not lose shims, if any, between the base and side frames.) Base may be left on machine during cleaning; remove only when necessary.

7. Erasure shield.—Loosen the set screw in the right pivot stud and remove the square detent stud. Slide the erasure shield to the right to disengage it from the left pivot.

8. Paper table.—Remove the mounting nuts beneath the paper table and pull the paper bail and detent release lever to the front of the machine. Remove the paper table. CAUTION: Do not lose spacers between the top of the bracket and the paper table.

9. Carriage end covers.—Raise right and left carriage end hinges. Release platen locks and remove the platen. Remove next the carriage end hinge pivot screws and remove the end hinges. Then remove the screws on the outside of the carriage end covers and remove the covers.

10. Rear carriage margin stop backpanel.—Remove the bevel head screw at each end of the panel and lift the panel out.

11. Carriage assembly.—Disconnect the draw band from the right end of the carriage and hook it over the anchor post on the back frame. Remove the upper carriage support bail roll, and the binding screws and the eccentric screw from each end of the carriage bed rail assembly. Pull the carriage forward and rock the top rearward. Remove the aligning scale and bracket and lift the carriage from the machine. Depress the shift when you pull the carriage forward.

12. Back frame.—Remove the two keepers from the margin release pull link and then remove the link. Remove next the top screws and loosen the bottom screws on the left and right side frames. Pull the top of the back frame rearward and down, and disconnect the spacebar tension spring from the back of the frame. Remove the nut and the eccentric screw from the bottom of the spacebar push link, and remove the screw from the adjusting guide and work spacebar push link from the machine. Then remove the bottom screws from the right and left side frames and remove the back frame.

13. Escapement frame.—To remove the escapement frame from the back frame, do the following:

a. Loosen the escapement link lock arm binding screw and disengage the escapement trip pull wire from the escapement rocker.

b. Remove the spring clip and spacer from the top of the backspace pawl. Disconnect the spring, remove the spring clip from the lower end of the pawl, and remove the backspace pawl.

c. Remove the spring clip from the line-lock operating lever stud and remove the lever.

d. Remove the hexagonal screws (3) with lock washers and then remove the escapement frame.

14. Escapement rocker assembly.—Position the escapement with the escape wheel facing you. Then loosen the lock nuts, the pivot screws, and remove the escapement rocker from the frame.

15. Escape wheel.—Remove the lock nut and washer from the bearing screw and remove the escape wheel. Then disassemble the loose dog silencer.

16. Disassembly of escapement rocker assembly. Proceed as follows:

a. Disconnect the loose dog spring from its guide.

b. Remove the loose dog fulcrum screw, the space washer, the locknut, and the washer.

c. Remove the loose dog carrying arm limit cushion screw, the locknut, and the washer.

d. Remove the loose dog assembly from the rocker.

e. Remove the loose dog guide screw and then the guide.

17. Disassembly of carriage.—Disassemble the carriage as follows:

a. Remove the linespace lever.

b. Pull the platen release lock forward and lift the platen out.

c. Remove the paper trough and feed rolls (front and rear).

d. Remove the tab stop screws and rack.

e. Remove the hexagonal binding screws from each end of the carriage support rail.

f. Remove the carriage release blade (nuts on carriage release lever) and slide the blade assembly to the left and out.

g. Remove the margin rack binding screws (2) and then the rack.

h. Remove the tabulator stop set assembly and then the carriage bed from the rail.

18. Margin release shaft.—Remove the spring clip from the rear extension of the margin release key and then the link from the stud. (Remove the spring from the ribbon lift

bellcrank assembly.) Next, remove the spring clip from the right end of the shaft and slide the shaft to the left until the right end is clear of the frame. Pull down and out to remove.

19. Ribbon control lever and link.—First, take the spring clip from the rear end of the ribbon control link. Then remove the nut, the spacer, the ribbon control lever, and the spring from the stud on the right side of the frame.

20. Ribbon control shaft and actuating lever assembly.—Loosen the set screws (2) in the ribbon control shaft control arm and remove the arm. Next, take out the two screws from the ribbon actuator arm bracket and disengage the ribbon lifter push link stud from the slot in the ribbon actuating lever. Then disengage the stud on the ribbon control shaft arm from the slot of the ribbon lifter push link. Remove the ribbon guide from the type guide and lift the assembly from the machine.

21. Ribbon spool shaft assemblies.—Disconnect the type bar restoring bail spring from its anchor post. Then remove the hexagonal screws (2) from each bracket and lift the assemblies from the machine.

22. Tabulator level shaft.—Remove the hexagonal screw from each end of the shaft and then take the shaft from the machine.

23. Ribbon drive shaft.—To remove the ribbon drive shaft, proceed as follows:

a. Slide the shaft to the right until the left end clears the drive gear.

b. Lift the left end of the shaft up into the opening of the left side frame.

c. Pull the shaft left enough to clear the right frame.

d. Pull the right end of the shaft forward and work the shaft from the machine.

24. Linelock universal bar (U-bar).—Loosen the head pivot screw from the right side frame to release the U-bar and then remove it from the machine.

25. Type bars and connecting links.—Remove the type bar fulcrum wire retaining screws (2) from the top corners of the segment casting. Then use a spare fulcrum wire to force the segment fulcrum wire out SLOWLY, and remove each type bar and link individually, starting with the first type bar on the left of the segment. Place each type bar connecting link in a wooden block (provided with the machine) and in the order removed. String type bars on a length of wire in the order removed.

26. Type bar cushion assembly.—Remove the screws (2) and then the cushion.

27. Type bar U-bar assembly.—Disconnect the oscillator spring from the anchor post. Then remove the screws (2) from the U-bar oscillator bracket and lift the assembly from the machine.

28. Segment.—Disconnect the segment balance springs and remove the segment pivot screws. Then lift the segment from the machine. CAUTION: Do not loosen the segment ball race bearings.

29. Segment shift rocker.—Partially unscrew the right segment rocker pivot screw and work the rocker from the machine.

30. Disassembly of platen and variable mechanism.—Remove the left platen knob, spacer and spring, and the variable cover plate screws. Put a finger over the left end of the platen and pull up the cover plate. Slide the variable linespacer lever dogs onto the platen shaft. Then remove the finger from the platen end and the variable linespace clutch ball and spring from the inside shaft. Finally, take out the variable linespace ratchet and the variable linespace dogs.

REPLACING TYPEFACE

To qualify for advancement to IM3, you must be able to replace the typeface, using a type bar soldering gage. A typical procedure is given in the paragraphs which follow.

Whenever typeface on one type bar is more than .003 inch out of line with the typeface on other type bars, the typeface which is out of line must be resoldered. To do the soldering, follow these steps:

1. Select from the typewriter a typebar next to the type bar to be resoldered, or one as close as possible to it (because of the angle of the type bar), which has perfect alignment and ring and platen setting, and a typeface on which the bottom of the small or lower case typeface aligns with that of the typeface to be soldered; such as, h, n, e, etc., or j, g, or y. The type bar you select will be used as a master type bar for setting the soldering gage.

2. Place the master type bar selected in a type bar soldering gage, as indicated in figure 15-13, with the type bar in the slot indicated in the illustration. Then tighten the head aligning screw.

3. Loosen the guide plate screw and so set the guide plate that it contacts both typefaces evenly, and with the guide plate stop just touching the bottom of the lower type.

4. Turn in the segment ring position screw just enough to have it contact the type bar at the segment ring position (fig. 15-13).

5. Repeat steps 3 and 4, making necessary corrections, and then remove the type bar from the soldering gage.

6. Remove the typeface from the type bar to be resoldered and clean all solder connection points on it and inside the type head thoroughly with a file.

7. Tin the type bar at the type position and inside the type head. To do this, heat the type bar and apply a small amount of soldering paste

(acid type) and sufficient solder to cover the surfaces at the point of solder connection.

8. Place the type bar in the gage and put the type in position, with the lower case type against the guide plate stop.

9. Heat the type bar just back of the head, as indicated in figure 15-13, with a torch; apply solder with a small amount of paste to the type bar and type at the point indicated. Use ONLY enough solder to make a full connection and to fill the space between the typeface and the type bar. (This is necessary to provide a solid back for the typeface, to prevent it from getting

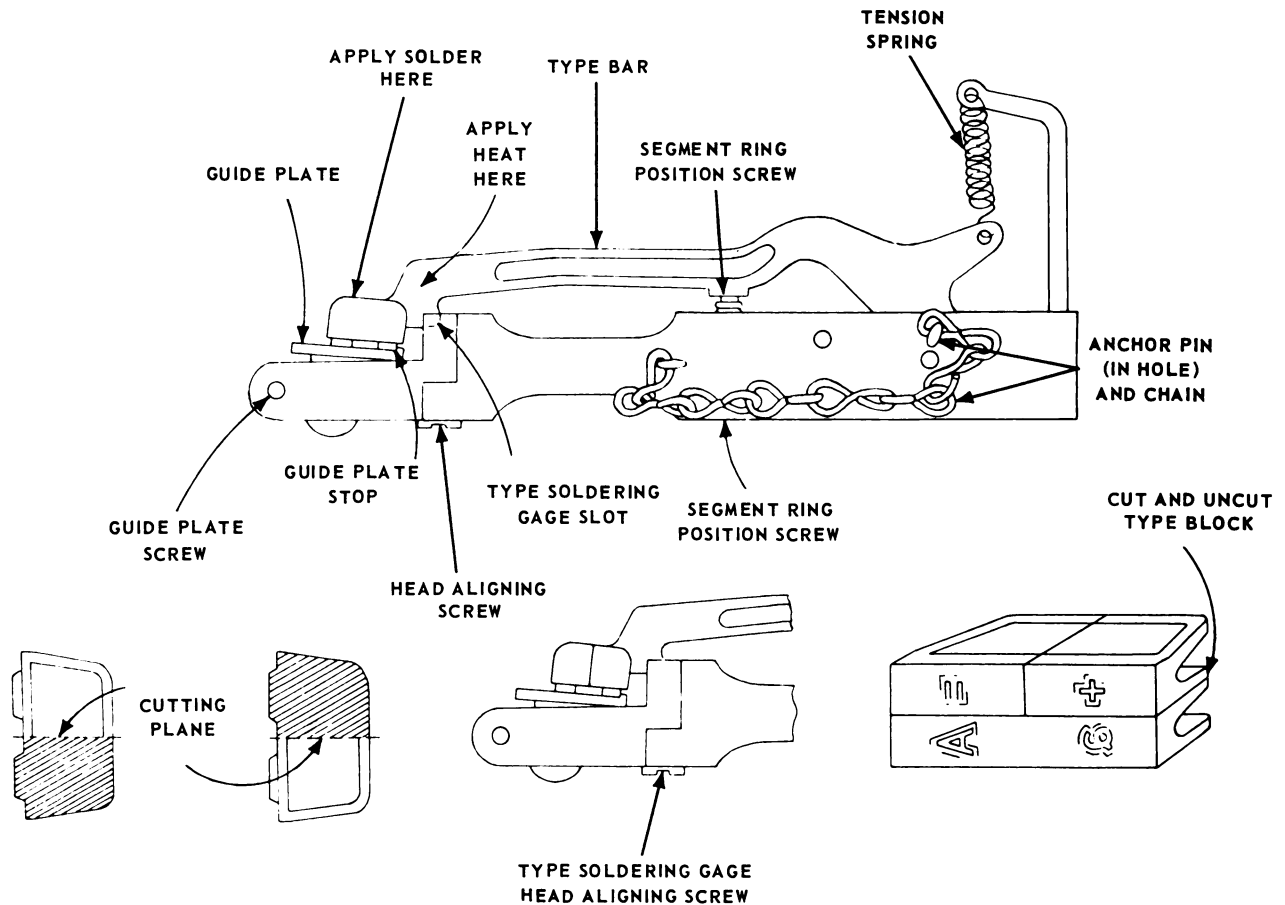


Figure 15-13.—Type soldering gage.

61.51X

loose when impressions are made.) If you use a soldering iron instead of a torch, apply the iron to the type head.

10. Clean off excess solder with a file.

11. Place the type bar back into the typewriter and make corrections, if necessary. Study the procedure outlined in the manufacturer's technical manual for making type alignment adjustments.

Although type heads (fig. 15-13) are furnished with many commonly used combinations of type characters, at times it becomes necessary to put on one type bar two characters which are not available on one type head. In this case, it is necessary that you cut two type heads and solder on the desired halves. This is known as split type.

When splitting type, proceed as follows:

1. Select two type heads which have the desired characters located correctly, upper and lower on the type head.

2. Grind the unwanted character off one type head, approximately 1/2 of the head, being sure that you have the edge of the cutting plane (fig. 15-13) at right angles from front to rear and side to side.

3. Grind off the unwanted character on the other type head in the same manner. Make certain that the amount you grind from this head is just enough to make the two pieces of type have the same dimensions when placed together as a single type head. A cut type head placed on an uncut type head is illustrated in figure 15-13.

CLEANING PROCEDURE

The recommended procedure for cleaning the Remington standard typewriter follows. Although this cleaning method is specifically recommended for Remington typewriters, it is also good for cleaning any make of standard typewriter.

1. Remove the panels, ribbon, platen, and rubber feed and bail rolls. (Rubber is damaged by the cleaning solution.)

2. Prepare a cleaning solution as recommended by the manufacturer of the basic cleaning agent specified by Remington Rand for cleaning their typewriters. Generally, 4 parts

of safety solvent, such as dry cleaning solvent or varsol, are added to 1 part of the cleaning agent.

3. Put the cleaning solution in the tank used for cleaning typewriters, or a typewriter washing machine. This machine consists of an oil tank with a specially constructed rack for holding the typewriter while an electric motor operates the machinery which raises and lowers it (up and down motion) in the cleaning solution. The speed at which the machine is raised and down is sufficient to agitate the solution to the extent necessary to force it into the recesses and crevices of the machine in order that it may dissolve dirt and grease.

4. Set the typewriter on the frame of the washing machine and run the machine for 15 minutes.

5. Remove the machine from the washer and wash it thoroughly under a hot water spray in a tank. Run the water long enough to remove all traces of the cleaning solution.

6. Put the typewriter on a metal drain board and dry the machine thoroughly with an air hose.

7. Oil the typewriter with No. 3 oil.

8. Put the machine in an electric oven (if available) and bake it for 15 minutes. The heat makes the oil thin and it then runs into the crevices of the machine.

9. Remove the typewriter from the oven and put it on a metal drain board as long as necessary to drain off excess oil.

10. Clean the platen and all rubber parts with a clean cloth moistened with alcohol or lacquer thinner.

11. Clean panels and other uncleaned parts with a clean cloth dampened with alcohol, or a recommended commercial solvent or cleaning agent.

If you do not have a special washing machine for typewriters, put the nozzle of an air hose in the bottom of the cleaning tank and keep passing through it while the typewriter is in the tank. It is best to have the air hose connected to a coiled copper tube, perforated at intervals placed in the bottom of the cleaning tank. The purpose of the air, of course, is to agitate the solution to the extent necessary to force it into the crevices in the typewriter.

INSPECTING AND REPAIRING

Inspecting and repairing as used in this section are limited to the work you do on a typewriter.

writer after you clean it. At this time, you should inspect all parts of the machine for defects or damage you may have overlooked during disassembly.

Bent links and levers in a typewriter may be straightened. Broken parts, of course, must be replaced. The rule to follow with respect to defects in parts is this: **REPLACE DEFECTIVE PARTS WHEN YOUR JUDGMENT TELLS YOU THEY WILL PROBABLY ADVERSELY AFFECT THE OPERATION OF THE TYPEWRITER.**

As you will learn through experience in typewriter shops, the greatest percentage of typewriter repair consists of the reshaping or the replacing of parts. If you understand the function of parts and mechanisms in a typewriter, you will soon learn through actual experience in instrument shops how to make all repairs on different makes and models. Precision in the work of a mechanic is the result of knowledge plus excellent experience.

REASSEMBLY

After you complete the repair work on a disassembled typewriter, your next task is to reassemble it. The step-by-step procedure for doing this is given in Table 15-1, for a Remington standard typewriter.

TESTING AND ADJUSTING

After you complete the reassembly of a typewriter, give it a thorough check to determine how various parts and mechanisms function. Make necessary adjustments as you test the machine.

The adjustment procedure described in this chapter is for the Remington standard typewriter. Adjustments for other makes and models vary in accordance with differences in construction and operation, so it will be necessary that you check the manufacturers' technical manuals

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Table 15-1.—Reassembly—Remington Standard Typewriter.

Name of Part	Assembly Procedure	Key Points
Variable Mechanism	a. Replace variable line spacer (VLS) ball spring. b. Replace VLS dogs and spring assembly. c. Replace VLS clutch ball. d. Replace VLS ratchet. e. Replace VLS ratchet plate. f. Replace platen knob. g. Depress VLS plunger and position dogs. h. Position ratchet in place. i. Position VLS cover plate and replace screws. j. Remove platen knob, left. k. Tighten VLS cover screws. l. Replace platen spacer spring, spacer, and knob.	Keep big end of spring up. So position the dogs that the longest side is up. Do NOT tighten screws. Large end of spacer must be outboard.
Segment shift rocker	Place rocker in position and secure it with the pivot screw and lock nut.	Rocker should work freely, but should have no end play.

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Segment	- Adjust V blocks for .025" between the rear of the V block and the side plate support bracket. - Place segment in position. - Replace segment race ball bearings. - Replace segment pivot screws and nuts. - Adjust right V block as necessary in order to eliminate side shake of segment.	Loosen the binding screw before you make the adjustments. Put screws in from LEFT to RIGHT. Do NOT use left-hand V block.
Segment shift toggle assembly	- Place toggle in position and connect to segment rocker. - Replace the rear toggle eccentric and binding screw. - Replace forward toggle eccentric, binding screw, and spacer. - Connect toggle to the right shift keylever extension and replace the binding screw and segment shift toggle yield link eccentric. - Connect the shift toggle spring to the anchor post.	For initial adjustments, position both eccentrics with the HIGH point down.
Type bar and connecting links.	- Start on the right and place the connecting link in the hole of the type bar. - Place connecting link in hole of bellcrank. - Place type bar in segment. - Insert fulcrum wire through hole of No. 44 type bar. - Repeat the above sequence to replace the remaining type bars. - Secure the fulcrum wire by replacing the lock screws (2).	On machines with 44 keys, hooks of connecting links 1 through 22 face outboard to the left in the type bars. Hooks of connecting links 23 through 44 face outboard to the right of the type bars. Connecting links 22 and 23 have flat surfaces. Connect the flat surface end to the type bar. Be sure fulcrum wire is clear of the lock screw hole before you replace the screw.
Type bar U-bar assembly	Put the assembly in position and replace the U-bar oscillator bracket screws. Connect the U-bar oscillator spring to the anchor post.	U-bar must work freely. There must be NO binds. Do NOT overlook U-bar stud compression spring.

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Linelock U-bar	Replace the pivot screw.	
Ribbon drive shaft	- First, check to determine whether the ribbon reverse cams are facing each other, and one high point is up and the other down. - Position the left end of the shaft in the crescent opening of the left side frame. - Work the right end of the shaft into the hole in the right frame. - Work the left end of the shaft into position.	Position the stud in the drive shaft arm.
Tab lever shaft assembly	Put in position and secure with two hexagonal screws.	On machines with 44 keys: - Tab CLEAR is between No. 15 and No. 16 bellcranks. - Tab KEY connecting link is between No. 18 and No. 19 bellcranks. - Tab SET connecting link is between No. 29 and No. 30 bellcranks.
Tab upstop shaft assembly	- Place in position, with the ribbon reverse bail engaged in the slot of the ribbon reverse collar, and the ribbon reverse detent stud in the slot of the right ribbon drive gear. - Secure the shaft with the two hexagonal screws. - Connect the linelock U-bar spring to the anchor. - Connect the margin release lever spring to the anchor.	The ribbon detent should NOT bottom in the slot.
Type bar cushion	Place in position and secure with screws (2).	
Ribbon spool shaft assembly	- Place in position and secure with hexagonal screws (2) in each bracket. - Connect the type bar restoring bail spring to the anchor (left side).	

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Ribbon control shaft assembly	- Insert the shaft into the hole in the ribbon. - Position the shaft in the hole of the right frame. - Position the stud of the ribbon control shaft control arm in the slot of the ribbon push link. - Position the stud of the ribbon lift push link in the slot of the ribbon actuator arm. - Position the ribbon guide in the type guide. - Secure the ribbon actuator arm bracket with screws. - Replace the ribbon control shaft arm.	This shaft should have minimum end play. Ribbon push link stud should be centered in the slot of the ribbon actuator arm when the type bar is against the segment anvil.
Ribbon control lever and link	- Replace the spring (flat detent). - Replace the spacer. - Replace the control lever and link assembly. - Secure with the lock nut. - Fasten the ribbon control shaft arm with the spring clip.	
Ribbon upstop plate	Position the plate with the stop down and secure it with four screws.	The ribbon actuator arm should almost touch the ribbon actuator arm stop when a type bar is against the anvil and the ribbon control lever is in the red position. More throw can be obtained by adjusting the ribbon U-bar eccentric. Position the high point of the ribbon U-bar eccentric to the rear.
		The ribbon lifter push link stud should contact the black upstop screw when the ribbon control lever is in the black position and a type bar is held against the platen. Adjust by turning the black upstop screw. Adjust the ribbon actuator arm by positioning the ribbon actuator arm stop.

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Margin release shaft assembly	- Replace through the bottom. - Place left end of the shaft in position. - Place the right end of the shaft in position and secure with the spring clip. - Connect the upper right extension to the margin release key and secure it with the spring clip. - Connect the ribbon lift bell-crank spring to the spring anchor on the margin release shaft.	
Carriage	- Replace the carriage bed rail. First, slide the carriage truck assembly onto the carriage roll rail; then slide the carriage bed rails over the trucks and the carriage roll rails from the right side. - Secure the tab stop set assembly to the bottom of the carriage with binding screws (2). - Replace the carriage release blade between the carriage ends. - Replace the tab rack between carriage ends and secure it with two binding screws. - Replace the margin stop rack on the rear of the carriage and secure it with binding screws (2). - Replace the carriage support rail and feed rack assembly, teeth downward, and secure it with binding screws (4). - Replace the front and rear feed rolls. - Replace the paper trough.	When the carriage rail left end is centered with the carriage, center the truck pinion with the small hole in the left end of the bed rail. Short end of the shaft and the tension spring go on the right end. The carriage release levers (right and left) are secured on the shaft with binding nuts (2). Open end of the rack should be forward. The carriage release blade spring should be forward on the right end of the tab rack. Be sure to install the draw band spring anchor on the right end when you insert the two binding screws there. Feed rack goes on the rear. Spring anchor goes to the rear of the support rail.

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Carriage (Continued)	i. Replace the platen. j. Replace the linespace lever. k. Position the rear carriage bed rail as necessary to remove the play from the carriage rail and carriage bed.	Loosen screws (6) and position the rail.
Escapement rocker	a. Replace the loose dog guide. b. Replace the loose dog assembly and secure it by replacing the fulcrum screw, the spacer, and the lock nut. c. Replace the loose dog limit cushion spring, the screw, and the nut. d. Connect the spring. e. Replace the tab friction arm compression spring.	There must be NO binds. Spacer goes between the loose dog and the escapement rocker. Check for .043" to .045" clearance between the loose dog and the rigid dog. Check with the loose dog limit cushion spring screw out, so that the loose and rigid dogs are opposite each other. To adjust, form the rigid dog.
Loose dog silencer and escape wheel	a. Replace the carriage support rail roller and lower the escape wheel onto the bearing screw. b. Place the wheel in such position that the loose dog silencer limit screw is in the slot of the silencer. c. Secure the escape wheel to the escapement frame with a lock washer and nut. d. Adjust the loose dog silencer limit screw.	Pica escape wheel has 15 teeth on it and 15 teeth on its pinion. Elite escape wheel has 18 teeth and its pinion has 18 teeth. Enough tension should be put on the loose dog silencer to hold the loose dog clear of the escapement wheel, thus eliminating noise.
Rocker assembly and compression spring	Place the assembly in position and secure it with pivot screws and lock nuts.	With the escape wheel held limited by the loose dog, the face of the escape wheel tooth and the face of the loose dog should be flush, referred to as the 6 o'clock position. Adjust by positioning the right escapement rocker pivot screw and nut.

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Rocker assembly and compression spring (Continued)		With an escape wheel tooth held directly behind the rigid dog, there should be .025" to .030" clearance between the rigid dog and the escape wheel. There will be .015" to .020" between the front edge of the loose dog and the front edge of a star wheel tooth. Adjust the lower escapement rocker limit screw to get proper dimensions.
Escapement frame	- Put the paper gasket in position at the top of the back frame. - Place the escapement frame in position and secure it with screws and lock washers. - Replace the linelock operating lever and secure it with the spring clip. - Replace the backspace pawl and secure it with spring clips (2) and then connect the spring. - Replace the escapement trip pull wire in position and secure the lock arm. - Replace the spacebar push link and push link adjusting guide.	Make certain that the bail toggle fits in the hole in the bottom of the tab friction screw arm. Spacer on upper stud goes on forward part of the pawl.
Back frame	- Put the frame in position, with the rear extension of the margin release shaft through the hole in the center of the bottom of the frame. - Replace the No. 3 screw in the back frame. - Replace the spacebar push link eccentric and secure the push link to the U-shaped connecting link with the screw and nut.	High point of the eccentric should be forward. The spacebar push link roll should contact the forward end of the escapement arm. Adjust by positioning the push link adjusting guide.
Carriage	- Place the aligning scale and bracket in position behind the ribbon guide. - Work the carriage into position and secure it by:	

Table 15-1.—Reassembly—Remington Standard Typewriter—Continued.

Name of Part	Assembly Procedure	Key Points
Carriage (Continued)	(1) Depressing the shift and replacing the carriage aligning scale bracket screws. (2) Replacing the binding screw and eccentric in each end of the carriage bed. (3) Replacing the upper carriage support rail roll and spacer and securing it with a spring clip. (4) Connecting the draw band to the anchor on the right end of the carriage. c. Replace the ribbon and make final adjustments (explained later).	Remove the upper roller, washer, and clip. Have the eccentric high point inboard. The spacer goes forward.
Panels	Replace in reverse order to the disassembly procedure.	

for these machines to learn how to make proper adjustments on them. Lack of space prohibits a discussion of the adjustment procedure of other typewriters in this chapter.

As you study the adjustment procedure for a particular part or mechanism of the Remington typewriter, refer to the applicable illustration.

Adjustment of Backspace Mechanism

The backspace mechanism is simple in construction and requires little adjustment. Parts of the mechanism must have freedom of movement. When the mechanism does not operate properly, make the following checks:

1. Tension of the pawl spring (fig. 15-7). The pawl spring must have enough tension to hold the pawl clear of the star wheel teeth.
2. Freedom of movement and wear of the pawl. If wear of the pawl interferes with proper action, replace it.

3. Alignment of the backspace keylever roll with the backspace lever arm. If the alignment is incorrect, adjust as necessary.

Adjustment of Spacebar Mechanism

Before you adjust the spacebar mechanism, check the adjustment of the escapement rocker body lower adjusting screw, and also loosen the escapement rocker body upper adjusting screw. The spacebar shaft should have freedom of movement but NO end play between the pivot points (fig. 15-5). Remove end play by adjusting the screw at the right end of the shaft; then secure the screw with the locknut.

The height of the spacebar should be 5/16" below the tops of the lowest row of alphabet keys. Make this adjustment by forming the spacebar upstops, and then check the linelock for proper locking of the spacebar.

The screw hole in the spacebar push link adjusting guide is elongated to allow adjustment of the spacebar push link to its proper position. For lighter space action, locate the push link roll near the front end of the arm. The spacebar push link roll must NOT touch the escapement rocker arm. Unhook the spring on the U-shaped connecting link and test the spacebar mechanism for freedom of movement. The spacebar push link must be free in its adjusting guide. When you make this test, hold forward the lower part of the escapement rocker body and check for binds. Escapement should take place just before the spacebar contacts the springs on the downstop screws. Hold the spacebar against these springs and adjust the upper rocker body stop screw enough to get .020" more movement in the escapement rocker body.

Ribbon Mechanism Adjustments

Refer to illustration 15-10 as you study the procedure for making adjustments to the ribbon mechanism.

Set the left margin stop at the end of the carriage and move the carriage to the right. Completely unwind the mainspring, and use the thumb to rotate the top of the mainspring to the right and to the left. While doing this, observe the ribbon shaft as it rotates and check for:

1. A DRAG OR BIND. If either exists, check the ribbon drive gear pinion for proper meshing with the ribbon drive gear. The pinion should mesh deeply with the drive gear but still have a slight amount of play. (Make this test also with opposite driving gears.)

2. CORRECT MESHING OF BALL CLUTCH PINION WITH THE SPRING DRUM GEAR. Adjust the pinion adjusting screw as necessary to have the pinion deeply meshed with the spring drum gear, but with a slight amount of end play.

With the carriage still at the right, depress the tabulator bar slowly and observe the movement of the ribbon throw-out screw and the pinion release bellcrank before the ball clutch pinion starts to move outward. There must be a slight amount of movement here. Depress the tab bar, and then the right and left carriage release levers to determine whether each disengages the clutch pinion from the spring drum gear. If the clutch pinion does not fully disengage, adjust the ribbon throw-out screw downward until disengagement is complete.

RIBBON REVERSE MECHANISM.—Before you adjust the ribbon reverse mechanism, make certain that you have proper ribbon spool shaft clearance and tension. The ribbon reverse detent stud should not mesh tightly in the right ribbon driving gear. There should be .008" clearance between the ribbon spool shaft collar and the bottom of the ribbon spool shaft bracket. Adjust accordingly by positioning the ribbon spool shaft pinion. The ribbon reverse plunger should have freedom of action. If there is a bind in this plunger, reshape it as necessary to remove the bind.

The ribbon spool shaft spring should have just enough tension to support a full ribbon spool and ribbon winding disk. Adjust as required by positioning the ribbon spool shaft collar.

Wind all the ribbon onto the left spool and then adjust the ribbon reverse and drive shaft in the following manner:

1. Loosen the right ribbon driving gear screw.
2. Position the ribbon reverse detent to the rear.
3. Loosen the ribbon reverse detent plate screws.
4. Position the ribbon reverse detent plate to the extent necessary to have proper meshing of the right ribbon driving gear with the right ribbon spool shaft pinion.
5. Tighten the ribbon reverse detent plate screws.
6. With the point of the right ribbon reverse plunger down, position the ribbon drive shaft as necessary to have the high point of the ribbon reverse cam up and a slight clearance between the cam and the plunger.
7. Tighten the right ribbon driving gear screw.
8. Position the ribbon detent toggle forward and position the left ribbon driving gear as required to have it mesh properly with the left ribbon spool shaft pinion.

The ribbon U-bar should have minimum end play. Make proper adjustments with the pivot screws. Adjust the ribbon U-bar fingers as necessary to have the keylevers contact the ribbon U-bar when the type bar is raised one half inch.

RIBBON COVER MECHANISM.—The following discussion of adjustments of the ribbon cover mechanism are for a typewriter equipped with

a 1/2" black and red ribbon. The black part must be adjusted for ribbon cover. Proceed as follows to make correct adjustments:

1. Adjust the ribbon U-bar (pivot screws in ends) so that its lips are in line with the key-lever. This bar must be free but must have NO end play.

2. Position the large side of the U-bar eccentric to the front of the machine and temporarily lock the eccentric. (May have to relocate later for finer adjustment.) Review illustration 15-9.

3. Remove the retainer and disconnect the ribbon lift bellcrank assembly from the ribbon U-bar toggle link. With the shift key depressed, bring the underscore type bar against the anvil. The edge of the ribbon should now be 1/32" below the underscore. If this is not so, form the stop of the ribbon actuator arm to get the correct position of the edge of the ribbon.

4. Set the ribbon selection lever in the stencil position (white dot) and check the position of the stud in the ribbon actuator arm. It should be in the center of this arm; if it is not in this position, release the screws in the shaft and arm which control it enough to enable you to position the stud properly. Retighten the screws. **CAUTION:** This initial adjustment must be exact.

5. Move the ribbon actuator arm stop to the rear and raise the upstop screw. Then put the ribbon selection lever on the red dot and, if necessary, reform any parts of the mechanism to have them function properly.

6. Move the ribbon selection lever to the blue dot and make corrections, if necessary, as you did in step four.

7. Depress the shift lock key and test for ribbon cover by typing a few capital H's (HHHH) in both black and red. The H should strike in the center of the black and red portions of the ribbon. If the type strikes too high on the ribbon, adjust the ribbon U-bar eccentric so that its high point is slightly toward the bottom of the machine. If the type is striking too low, reverse this procedure. Then test for ribbon cover again by typing the entire alphabet and figures in both upper and lower case. To prevent overthrow or underthrow of the ribbon, you must **CORRECTLY ADJUST THE ECCENTRIC**. If two or three keylevers throw the ribbon too high or too low, make correction by forming the corresponding fingers on the ribbon U-bar.

8. Place the ribbon selection lever on the black dot and so adjust the black upstop screw

that the ribbon U-bar has just a little downward movement left.

9. Put the ribbon selection lever on the red dot and so adjust the ribbon actuator arm stop that just a bit of downward movement remains in the ribbon U-bar.

10. If the ribbon carrier moves when you shift the ribbon selection lever, the fingers of the ribbon U-bar may be too high, the ribbon actuator arm stop may be formed too low, the stud in the ribbon lift bellcrank may not be in line with the hole in the arm, or the high point of the ribbon U-bar eccentric may not be toward the front of the machine.

Key Restorer Mechanism

The type bar restoring mechanism on a Remington standard typewriter releases and restores collided type bars near the type bar guide. Study illustration 15-14. When the restorer key is depressed, it strikes the bellcranks of collided type bars and returns the type bars to their normal rest positions.

When in the rest position, the restorer should not touch the side frame connecting rod (fig. 15-14) adjacent to it; and it should not contact the bellcranks when a center type bar is held against the platen. You can correct either difficulty by forming the key restorer lever connecting shaft where it contacts the restorer.

Shift Mechanism Adjustments

When adjusting the shift mechanism, it is very important that you have freedom of movement but minimum end play of all pivot points. Excess end play results in poor ON-FEET and MOTION alignment. (The term ON-FEET means a type bar is so formed that upper and lower case characters on the type heads print with equal density.) You can remove end play in the shift keylever shaft by adjusting the pivot screws on the right side of the frame. Study the illustration of the shift mechanism in the manufacturer's technical manual.

Make ON-FEET and MOTION adjustments in the following manner:

1. Loosen front and rear segment stop screws to prevent their limiting segment travel.

2. Position the high points of the shift toggle eccentrics down.

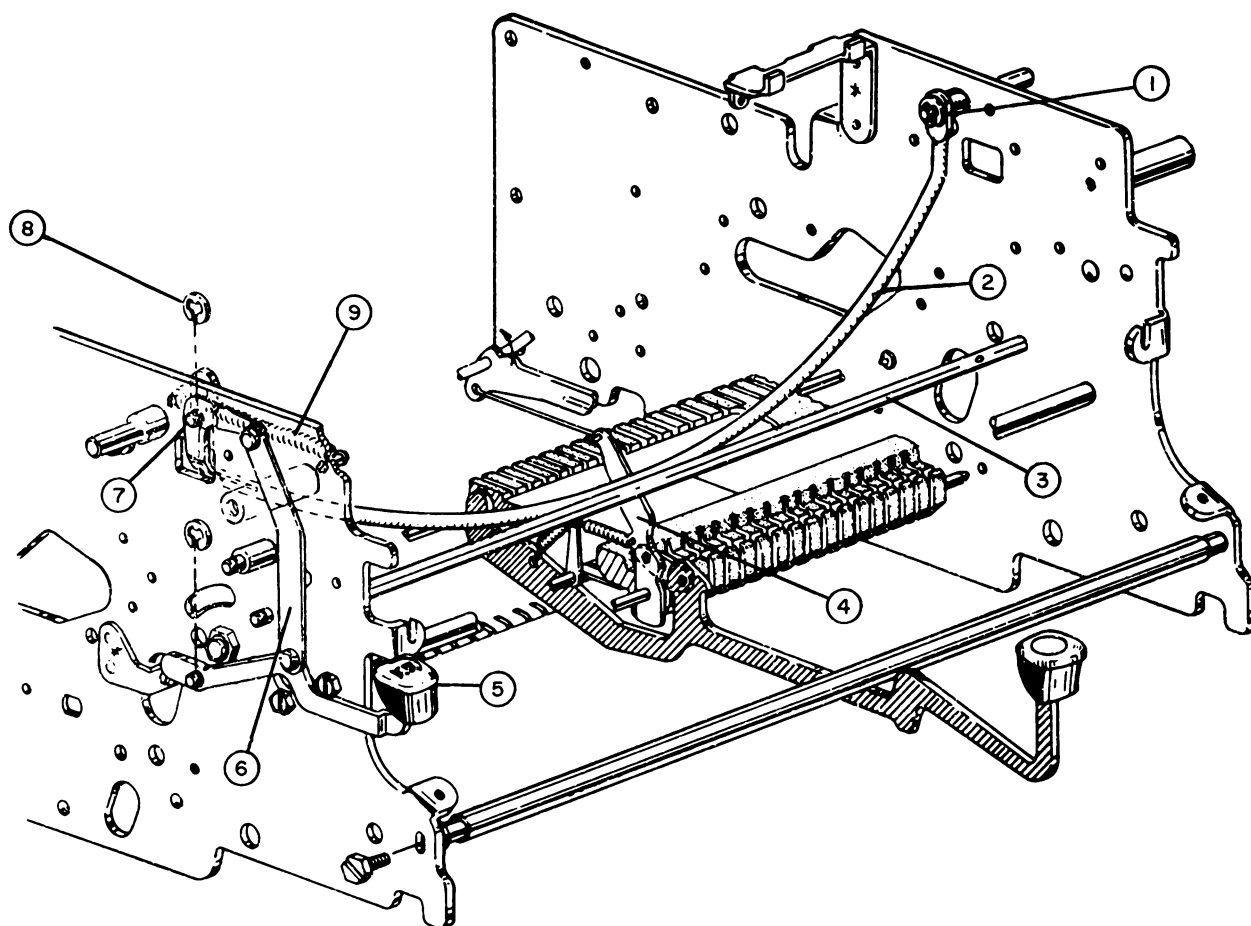
3. Adjust the shift toggle cushion eccentrics so that the toggle levers make a straight line

when the type bar segment is in either the upper or lower case position.

4. Depress the shift key and adjust the forward eccentric for on-feet adjustments. Move the high point of the eccentric toward the front of the machine to raise the segment and toward the rear to lower the segment. Check the upper case lock; if there is none, recheck step three.

5. Position the front segment stop screw to the extent necessary to remove excess up and down play when the shift key is depressed.

6. Adjust the rear eccentric for MOTION. Then test for motion by typing small and large H's alternately (HhHhHh). Bottoms of all H's must be in line. Check lower case lock and then recheck step three.



- | | |
|------------------------|--------------------------------|
| 1. Restorer pivot stud | 6. Type bar restorer key lever |
| 2. Restorer | 7. Restorer pivot stud |
| 3. Ribbon feed shaft | 8. Keeper |
| 4. Bellcrank | 9. Type bar restorer spring |
| 5. Restorer key | |

Figure 15-14.—Key restorer mechanism.

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7. Position the rear segment stop screw as necessary to remove excess up and down play when the shift toggle is near the latching point. **CAUTION:** Make certain the eccentric screws are tight.

8. Sufficiently adjust the eccentric below the shift yielding spring to position the top of the shift key 1/16" above the top of the lower bank of keys.

9. Shift lock plates must be set evenly. Position them so that motion will be held when the shift keys are in the LOCK position. Both plates should hold the shift key assembly in the same position.

The segment is adjusted at the factory by accurate gages and adjustment is seldom necessary; but if it is necessary, or a bind was put in the segment during shipment, make adjustment by screwing in or out on the RIGHT segment ball race block screws. Retighten the screws when adjustment is complete.

Card Holder Adjustments

The transparent card holders on the Remington standard typewriter enable the operator of the machine to insert paper without raising the paper bail. These holders have locking arms which can be positioned to get proper action in accordance with the type of cards or holders inserted into the machine.

When the locking arms are positioned toward the OUTSIDE of the machine, the transparent card holders are held forward, farther away from the platen. When the locking arms are in a vertical position, the card holders are in their normal position; but they can yield forward, if necessary. If the arms are set toward the center of the machine, the card holders are held in their normal position, with NO yielding in any direction.

Aligning Scale Adjustments

You can adjust the aligning scale by forming the aligning scale bracket so that six sheets of paper may be placed between the scale and the platen. Type some i's (iiii) and adjust the aligning scale so that there is a fine line of space between its top and the bottom of the printed line of i's. At the same time, so position the aligning scale laterally that the white lines on it will be in line with the vertical lines of the printed i's.

Adjustments of Margin, Linelock and Bell

Take another look at illustration 15-6 as you study the procedure for adjusting the margin release and linelock mechanism.

Adjust the margin release toggle connecting arm (margin release push link also, if necessary) to the extent necessary to have the margin stop release blade clear the stop plates of the right and left margin stops. **CAUTION:** You must not have too much clearance.

Position the margin stop rack as necessary to have the left margin stop clear the margin stop release blade by .050" to .060" when the carriage is to the right. Move the left margin stop inboard and check from the front with a feeler gage. Recheck the 6 o'clock position. Position the rubber stop the amount required to have it absorb the shock from the carriage as it returns to the left margin. Adjust the margin blade buffer cushion (rubber eccentric) as necessary to have it JUST CONTACT the margin blade buffer.

The bell should ring 8 to 10 spaces before the line is locked. You can make proper adjustments by moving the bell slide cam to the right or to the left.

When the carriage is against the right margin and the keyboard is locked, the linelock adjusting plate should be against the margin stop release blade. Adjust by positioning the linelock adjusting plate eccentric.

Check your adjustments by tabulating to the right margin and checking the stopped position of the carriage. Then depress the backspace key to determine whether it will move the carriage farther to the right. If the carriage is not in proper position, or if it moves a space to the right when you depress the backspace key, recheck all your previous adjustments of the mechanism.

You can correctly position the escape wheel so as to allow reliable backspacing out of the right margin by:

1. Positioning the left and right stops 20 spaces apart.
2. From the left stop, typing 20 characters.
3. Positioning the adjusting plate so that it just touches the margin stop release blade.

The bell mounting hole is off center, to allow for adjustments of the bell. It should be so adjusted that it clears the hammer by about .020

inch. If the bell rings when the carriage is returned, there is not enough clearance between the hammer and the bell. Correct this difficulty by reforming the hammer.

Tabulator Mechanism Adjustments

The tabulator mechanism of a Remington standard typewriter is shown in figure 15-11.

The tabulator key bar lever, the tab set keylever, and the tab clear keylever bellcrank springs must have sufficient tension to hold their respective keylevers against the upstop. The down stops for tab keylevers are the extended portions of the keylever comb.

Make adjustments of the tabulator mechanism as follows:

1. When the tab key is depressed, the tabulator blade should center between the two tab stops. Adjust by positioning the tabulator rack (adjusting screw and locknut in right end of carriage).
2. The tab set arm should contact **ONLY ONE** tab stop when the tab set key is depressed. Make adjustments by positioning the tab set bracket.
3. The tabulator bellcrank adjusting screws should just clear their respective blades by about .010 inch. Adjust by turning the screws.
4. When the tabulator clear key is depressed, the top of the tabulator blade must clear the bottom of the tabulator stop rack by 1/32 inch.
5. When the tabulator key is depressed, the **TAB CLEAR** blade should clear the tab stops in their normal positions. Adjust by turning the tab clear blade bellcrank adjusting screw.
6. The tab set arm should clear the tabs in their normal positions and fully depress a tab stop when the tab set key is depressed. Make necessary adjustments by forming the lips of the tab set arms.
7. The tabulator friction study should seat flush on the star wheel when the tab key is depressed. Make essential adjustments by turning the tab friction arm support screw. If the tab stop blade hangs on a tab stop and will not restore, move the support screw toward the front of the machine to relieve pressure on the star wheel.
8. The tabulator friction stud should clear the star wheel in its normal position. Make required adjustments by forming the lower end of the tab friction screw arm toward the front of the machine.

9. Smooth, rapid travel of the carriage during tabulation can be procured through proper adjustment of the tab friction spring. Turn the adjustment screw as necessary and then lock the nut.

10. When the tab bar is depressed, the loose dog release lip should lower the loose dog **JUST ENOUGH** to clear the star wheel—not far enough to limit the loose dog in its guide. Form the loose dog release lip enough to get proper adjustment.

Linespace and Carriage Adjustments

Before you start to make adjustments on the linespace mechanism, check first to determine whether a shiny platen or glazed feed rolls are responsible for improper feeding of paper.

LINESPACE ADJUSTMENTS.—When the left platen knob is tight, the variable linespace shaft must have a slight amount of end play. Make tests with the variable set at various positions. Lack of end play prevents the clutch plunger springs from securely forcing the clutch plunger to the cam variable linespace lever dogs into the teeth of the ratchet, which is necessary in order to have even spacing between lines.

Check for freedom (without end play) of the platen in its bushings. To remove end play, loosen the adjustment screw in the right platen knob and turn in on the knob until there is no end play in the platen when you spin it. Retighten the screw. (Study the different parts in the applicable illustrations.)

The linespace pawl arm on the Remington standard typewriter has been extended forward, and a hardened button stud has been added to the linespace regulator to contact the arm, eliminating the link formerly used. The linespace lever works in conjunction with the carriage end panels.

With the paper bail raised, the feed roll release lever pulled forward, and the linespace regulator set to the rear, move the linespace lever slowly to the **RIGHT**. Observe the engagement of the rear portion of the linespace pawl with the teeth of the ratchet and the lower portion of the linespace pawl with the platen ratchet. Hold the linespace lever to the right as far as it will go and try to turn the platen. It is securely locked in position. At this point, adjust the ratchet detent arm eccentric enough to have the detent roll resting between two teeth of the platen ratchet. This is a very important ad-

justment, for the detent must hold the ratchet in the position placed by the linespace lever.

The linespace ratchet detent arm spring must have enough tension to centralize the detent roll between two variable linespace ratchet teeth when you turn the platen slightly forward or rearward. You can make proper adjustment by positioning the spring anchor eccentric.

Operate the linespace lever to its limit and release it slowly, observing at the same time whether the platen ratchet creeps slightly to the front or to the rear of the machine. Then test the machine with the linespace regulator set at the DOUBLE and TRIPLE space positions.

To check the pressure exerted by the front and rear feed rolls, place two small strips of paper 1" wide between the platen and the rear outside feed rolls, but not far enough in for the front feed rolls to grip them. Then pull on each strip alternately to determine whether the rear feed roll has a firm, even tension at both ends. Adjust rear feed roll pressure springs as necessary to get even pressure. Make this same test on the front feed rolls and adjust as necessary to get proper pressure.

Even pressure of the bail roll on the platen can be obtained by correctly forming the bail arms.

ADJUSTMENT OF CARRIAGE SCALES.—When you make adjustments on carriage scales, set the left margin stop to the extreme left end of the carriage.

The carriage scale is mounted in the same manner as the paper bail scale, and the adjusted carriage scale can be used to set the paper bail scale.

Position the carriage so that zero (red figures) is in line with the pointer on the type guide. Put paper in the carriage and place a pencil in the slot of the type guide (top). With the point of the pencil against the paper, rotate the platen. Your vertical mark on the paper should be in line with zero on the paper bail scale. If this is not true, loosen the screws at both ends of the paper bail scale and adjust as necessary to get this condition. If necessary, re-form the paper bail arms.

The aligning scale should be distant from the platen the thickness of six sheets of paper. It should be .005" below the writing line, and its white lines should line up with the letter I. Make proper adjustments by loosening the screws and positioning the scale.

PAPER TABLE AND MARGIN STOP SCALE.—To adjust the paper table, put a sheet of 8 1/2 x 11 paper in the typewriter and turn the platen until both ends meet above the platen. Adjust the top edges and corners to get proper alignment. Release the feed roll lever and check to ascertain whether the numbers and graduation marks on the front scale of the paper table correspond with the upper half of the carriage scale and bail scale. If they do not correspond, unloosen the two nuts on the underneath side of the paper table and make proper adjustment.

Carriage Adjustments

The carriage support brackets are mounted to the underside of the bed rail by two screws. The inside slots of these support brackets have elongated holes for screws, and at the rear of the brackets are eccentrics which are used to adjust the carriage to the front or back to obtain cylinder and anvil position. They are correctly adjusted when the carriage is parallel to the machine; and when the type bars are held at anvil position, with one sheet of paper in the carriage, the type should bite the strip of paper at the platen and anvil with the same pressure.

When adjusting the carriage, follow these rules:

1. Adjust the carriage support rail so that the bottom of the rail just touches the lower carriage support rail roller. Make necessary adjustments by lowering or raising the carriage support rail.

2. Adjust and position the carriage feed rack to the extent necessary to have it mesh evenly and fairly deep (never to the bottom) with the escape wheel pinion.

3. Adjust the carriage support rail roller so that it barely clears the top of the carriage support rail. This clearance should be exactly .002 inch.

Escapement Adjustments

Refer to the escapement mechanism shown in figure 15-4 as you study the procedure for adjusting it. First, adjust the feed rack to the degree necessary to have its teeth mesh fairly deeply and evenly in the teeth of the escape wheel pinion. CAUTION: If these teeth BOTTOM in the teeth of the escape wheel pinion, piling of letters and a noisy carriage result. Move the feed rack

up and down on the feed rack mounting screws, as necessary, until you have proper adjustment.

To adjust the loose dog silencer, loosen the set screw which holds it and turn the adjusting threaded collar until you have proper tension, just enough to hold the loose dog clear of the escape wheel teeth as the carriage is returned. CAUTION: The rear side of the adjusting collar should not extend beyond the back edge of the escape wheel. TOO MUCH tension causes sluggish operation of the carriage. Re-tighten screws in the collar when the tension is as desired.

Adjust the escapement loose dog carrying arm screw so that you have a minimum amount of play. Check the loose dog for freedom of movement in the loose dog guide, up and down and right or left. The correct distance between the loose dog and the rigid dog is from .043 inch to .045 inch.

Hold the face of the loose dog flush against the teeth of the escape wheel (commonly known as 6 o'clock condition) and adjust for this condition by moving the escapement rocker pivot screws to the right or to the left to get desired results. Then check for freedom of action of the rocker, with NO end play.

Raise the H type bar to the ribbon. The escapement should trip as soon as the face of the type touches the ribbon. To adjust, loosen the escapement link nut and adjust the escapement link sleeve in the amount necessary to have the trip take place when a typeface touches the ribbon. If all type bars do not trip at the same position, adjust the ends of the U-bar to center the type bars.

Hold a type bar head against the platen and check the lower part of the escapement rocker for a small amount of additional forward movement. (The upper escapement stop screw should not limit the movement of the escapement rocker.) Then make the same test with the spacebar depressed against its down stops. If forward movement of the escapement rocker is not the same, check all spacebar adjustments and test again. If the rocker still limits against the upper stop screw, turn this screw slightly counterclockwise.

To test the escapement SAFETY ZONE, raise the H type bar slowly by hand until it touches the ribbon and escapement takes place. Then allow the type bar to restore slowly to its rest position (front). The second trip should occur when the face of the type bar is $1/2''$ to $9/16''$ away from the ribbon. If the distance is more

than $9/16''$, letters may pile on top of each other; if the distance is less than $1/2''$, skipping between letters may occur. Check the distance between the loose and rigid dogs to make certain that it is between .043'' to .045''. If the escapement loose dog carrying arm screw is TOO tight, it prevents the loose dog from stepping to the left, causing the machine to pile up letters occasionally.

Adjustments of Type Bar U-Bar

To test adjustment on the type bar U-bar, raise the H type bar to the ribbon and check the escapement action. If this is correct, raise by hand type bars No. 1 and No. 42 to ascertain whether escapement takes place when the face of the type touches the ribbon. If all three type bars cause the escapement to trip when the typeface touches the ribbon, the U-bar is correctly adjusted.

If the No. 1 type bar were to cause the escapement to trip when it was still $1/8''$ away from the ribbon, you would make correction by loosening the left type bar U-bar oscillator pivot screw and locknut, and moving the screw slightly to the rear. After you make this adjustment, always check No. 42 type bar for trip action. When you move the LEFT type bar U-bar oscillator pivot screw to the rear, escapement on No. 42 type bar occurs a little sooner than it did before. When you move the LEFT type bar U-bar oscillator pivot screw forward to make escapement on No. 1 type bar occur sooner, it causes escapement on the No. 42 type bar to occur later.

Adjustment pivot screws are provided at both ends of the type bar U-bar oscillator bracket. If escapement on the No. 42 type bar does not take place at the ribbon after you locate the left type bar U-bar oscillator pivot screw, follow the same procedure for properly locating the RIGHT type bar U-bar oscillator pivot screw.

Platen Adjustments

The platen should turn freely, with no noticeable end play. Adjust by turning the right platen thumb wheel. You can remove up and down play from the platen by adjusting the platen lock lever eccentric.

The paper feed rolls should have enough tension to cause the platen to turn as you pull a single sheet of paper from the machine; and

all feed rolls should have equal tension. Adjust the feed roll tension by turning the feed roll tension spring screws.

Paper bail rolls should seat on the platen. Make necessary adjustments by forming the paper bail assembly arms. The paper bail scale can be adjusted laterally to line up with the margin scale. To adjust the scale, loosen the screws and position the scale. Adjust the ring and cylinder with the carriage binding screws and eccentrics (left and right) with one sheet of paper in the machine.

For additional information on adjustments of parts and mechanisms of the Remington standard typewriter, consult the manufacturer's technical manual for the machine.

ELECTRIC TYPEWRITERS

This section discusses the operation of an electric typewriter and gives some of the procedure for adjusting it. To qualify for advancement

in rate to IM3, you must understand how an electric typewriter works.

Space in this text does not allow a detailed discussion of several makes and models of electric typewriters, but one representative make is discussed in sufficient detail to enable you to understand how it operates. All typewriters have parts which are similar, but they do not operate in the same manner. All electric typewriters have motors which provide power for operating parts and mechanisms, but the parts are not all alike in design nor do they function exactly the same. The best way to learn these differences, therefore, is by working on the typewriters, with the manufacturer's technical manual for a particular model available for ready reference. Some similarities and differences are pointed out in this section.

Study the nomenclature of the Smith-Corona electric typewriter illustrated in figure 15-15. Then take a look at the Royal electric typewriter shown in figure 15-16. Figure 15-17 shows an IBM electric typewriter, Model C-1 machine selected for discussion in this section.

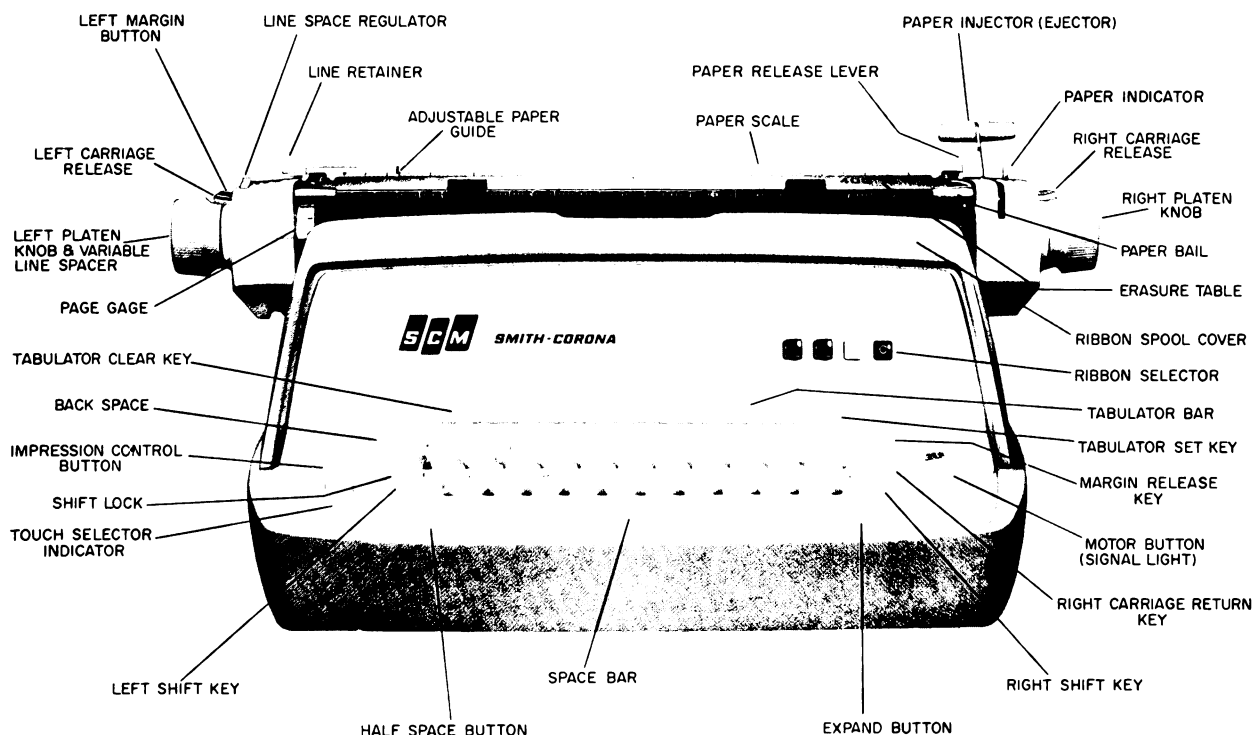


Figure 15-15.—Smith-Corona electric typewriter.

61.37X

PARTS AND MECHANISMS

Before you can understand the operation of an electric typewriter, you must know and understand the function of various parts and mechanisms which comprise it. These are discussed first, and illustrations are given in sufficient number to enable you to understand how the mechanisms function. By studying each illustration as you read the discussion applicable to it, you will get a clear picture of the operation of an electric typewriter and understand how its parts and mechanisms differ from those of a manual typewriter.

Motor and Electrical System

The heart of an electric typewriter is the motor and electrical system (fig. 15-18). The motor (115V-60 cycle) is rated at 1/40 horsepower and runs at a speed of approximately 1625 revolutions per minute (rpm). No governor, brushes, or starting contacts are required. The capacitor in the starting winding circuit provides starting torque and direction to the motor. Except for the switch, the entire electrical system is mounted on the rear frame, making it readily accessible for inspection by removing the frame.

Figure 15-19 shows how the power from the motor is transmitted by belts and pulleys to the power roll. Note the names of the two belts, and the teeth on them. Speed reduction from the

motor to the power roll is approximately 6:1. Different combinations of pulleys give different speed reductions. Power roll speed can be varied by using pulleys of different size on the motor, two sizes of which are available in the C-1 machine. A 14-tooth pulley provides a power roll speed of 242 rpm, or 95 feet per minute (fpm). A 15-tooth pulley provides a power roll speed of 261 rpm, or 103 fpm.

Power Roll

The purpose of the power roll is to drive the cams (explained later) which operate the type bars and perform other functions. This roll consists of a rubber sleeve glued over a metal cylinder. Serrations of letter and functional cams engage the rubber surface of the power roll and move with it. The complete power roll assembly is shown in figure 15-20.

The rubber covering of the power roll must be resilient enough to ensure good friction with the cams and at the same time tough enough to resist wear and abrasions from the cams. An anti-oxidizing wax added to the rubber gives it these qualities and prevents hardening. Eventually, however, it becomes too hard to give good impressions and the roller must be replaced. The wax goes to the surface of the power roll and lubricates it; but it also gets on the cams and clogs their serrations, and builds up deposits on their sides. Wax on the surface of the roll may cause impression difficulties, and wax on the sides of the cams may cause



61.37X
Figure 15-16.—Royal electric typewriter.



61.37X
Figure 15-17.—IBM electric typewriter.

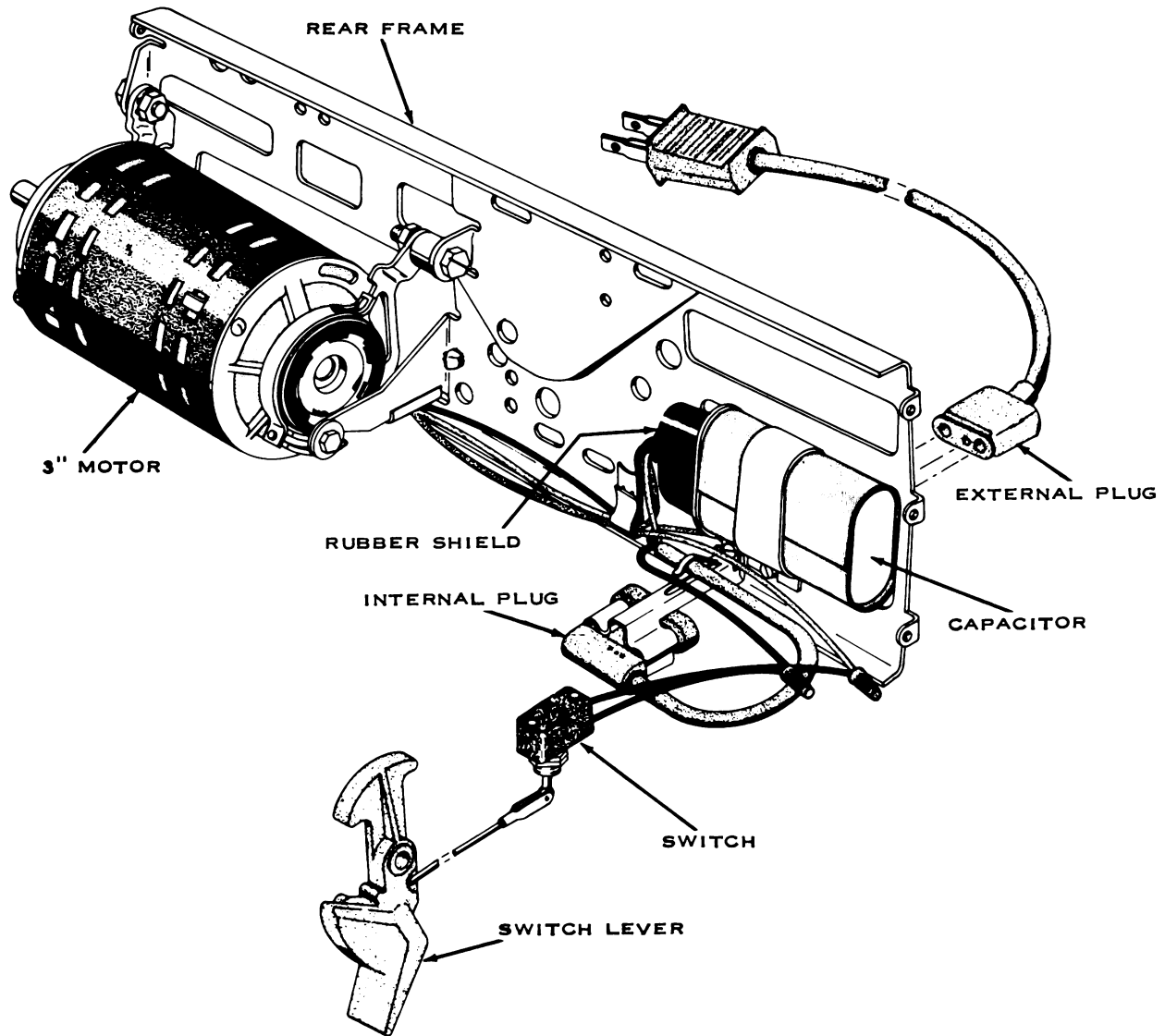


Figure 15-18.—Motor and electrical system.

91.6X

repetition. It is therefore advisable to clean the surface of the power roll when it is installed and at periodic intervals thereafter.

Letter Keylevers

The method of mounting keylevers in the IBM electric typewriter is illustrated in figure 15-21. They are supported at the rear by a fulcrum rod which passes through a hole in each keylever. The fulcrum rod is held at each end by the keylever bearing support which is

mounted to the side frames. The forward end of the keylever bearing support may be raised or lowered to adjust the height of the keylever fulcrum rod, and to allow for adjustment of clearance between keylever lugs and the cam trip levers.

The keylever guide comb serves to space and control the forward ends of the keylevers. Keylever springs (fig. 15-21) hold the keylevers in their rest positions against the upper stop, located between the third and fourth rows of keylevers. To provide uniform touch, a spring

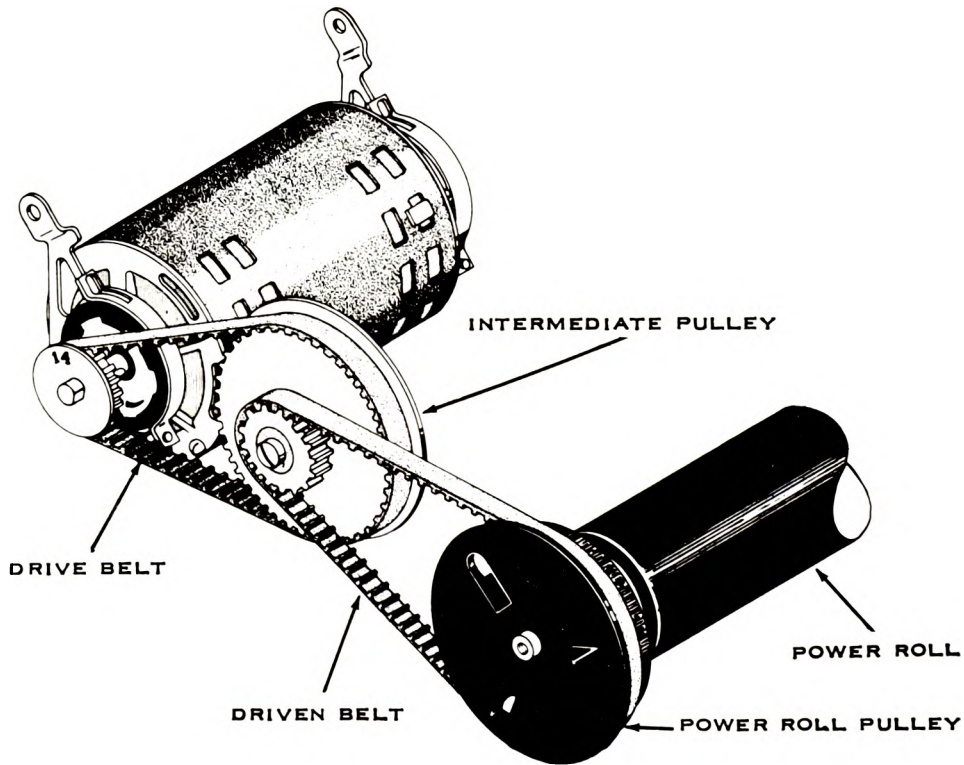


Figure 15-19.—Positive belt drive.

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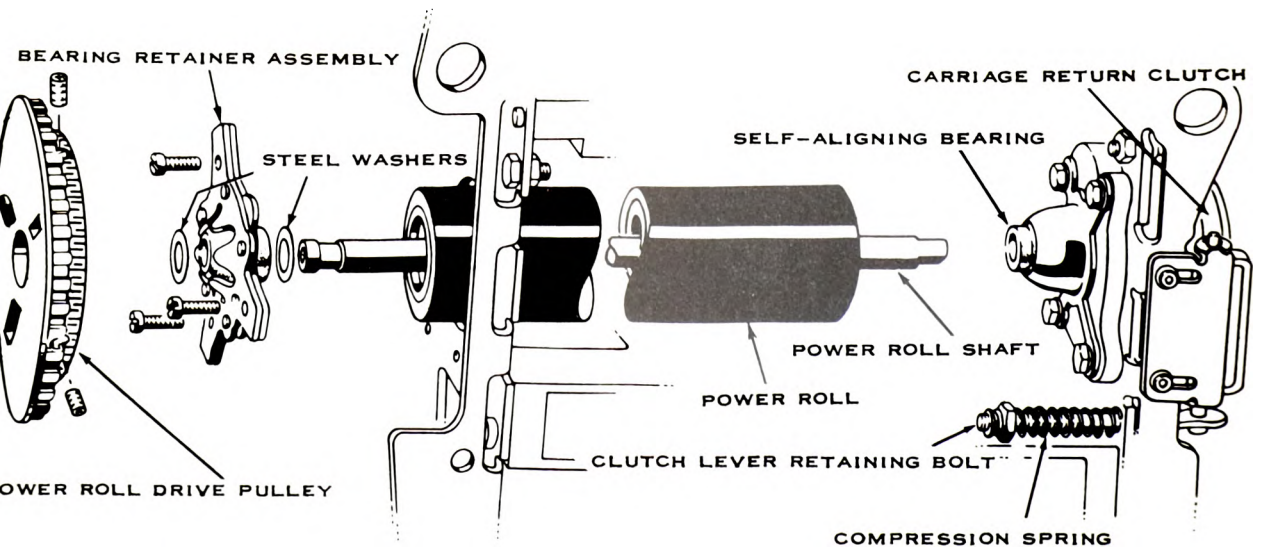


Figure 15-20.—Power roll mechanism.

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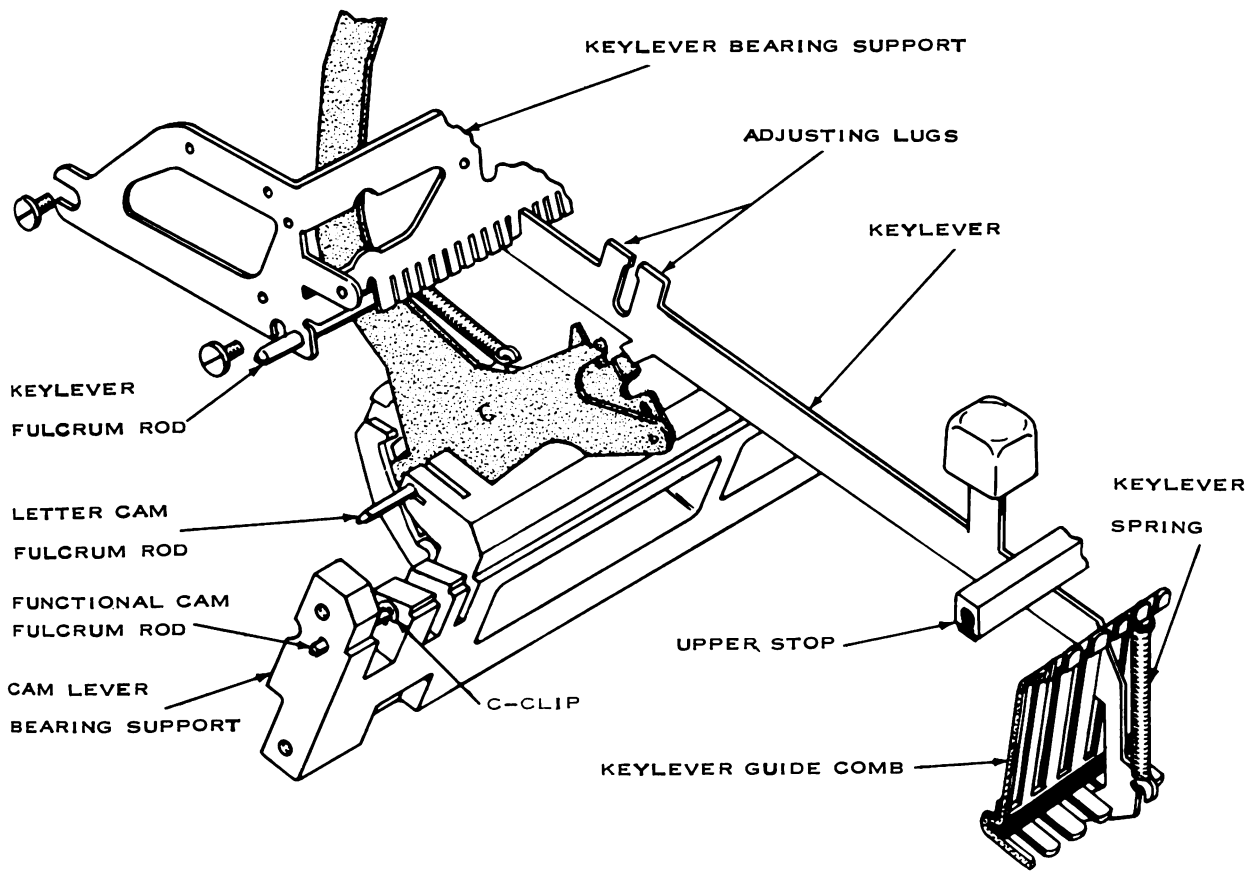


Figure 15-21.—Keylever mounting.

91.9X

of different tension is used for keylevers in each row of the keyboard.

Letter Cams

Letter cam assemblies are mounted in slots in the cam bearing support and are held by a fulcrum rod which passes through a hole in each cam lever. Study figure 15-22 carefully. A link connects the type bar with the cam lever.

Cams are made of nylon molded over a steel body. The nylon reduces wear and requires no lubrication. The steel body gives rigidity and maintains uniform cam size during temperature and humidity changes. As illustrated, the cam is mounted to the cam lever by a shoulder rivet about which it rotates. A cam spring from the cam to the cam lever holds the cam in its rest position. The heel of the nylon shoe contacts the cam lever when the cam is fully rotated and

limits its rotation. In normal operation, however, the cam does not rotate this far; its head contacts the knockout finger and knocks the cam off the power roll before it reaches this limit. The rise of the cam, pushing from the power roll against the cam rivet, causes the cam lever to pivot about its fulcrum.

Note the trip lever. It is mounted to the cam lever by a shoulder rivet through a slot in the trip lever. This slot allows the trip lever to slide forward and backward on the rivet and also to rotate about it. A spring holds the trip lever up and to the rear in its rest position. The trip lever has two formed lugs, upper and lower. The upper lug is positioned directly beneath the keylever lug, and the lower lug is directly above the cam. After the type bar strikes the platen, the type bar and cam lever reverse direction and return to the rest positions.

If a keylever is held down, the rear edge of the upper lug on the trip lever engages the front edge of the lug on the keylever as the cam lever assembly restores. See figure 15-23. The trip lever slides on its mounting stud as the cam lever restores to its rest position, and remains against the front of the keylever lug until the keylever is raised. When the keylever is raised, the trip lever spring restores the trip lever to the rear beneath the keylever lug. This sliding action of the trip lever ensures a single operation of the cam and allows the type bar to restore to its rest position, even though the keylever is held down.

The position of the cam knockout fingers (fig. 15-24) controls type impression. Note the individual cam adjusting screw, one of which is below each knockout finger. By raising or lowering the entire cam knockout assembly as a unit, an operator can change the knockout point of all the cams. This can be accomplished by rotating the impression control lever, which rotates the eccentric shaft to raise or lower the knockout bar. Raising the bar decreases the impression of all type bars; lowering the bar

increases the impression of all type bars. The scale on the impression control lever is graduated from 0 to 10, but the typewriter is adjusted at the factory for uniform impressions when the control lever is set at 5.

Type Bar Segment

The type bar segment is a semicircular steel casting with slots cut into it to mount and guide the type bars. It also provides the mounting for the universal bar and the type guide, which is formed of heavy metal and attached to the segment by screws and a dowel pin (fig. 15-25).

Note the ring in the segment. As a type bar approaches printing position, it rises through its slot and the type slug enters the type guide. Just before the typeface contacts the paper on the platen the type bar strikes the ring of the type guide (fig. 15-25), which whips (bends) the portion of the type bar above the ring and causes the typeface to print. This whipping action prevents lingering of the typeface on the paper and smearing the impression it made.

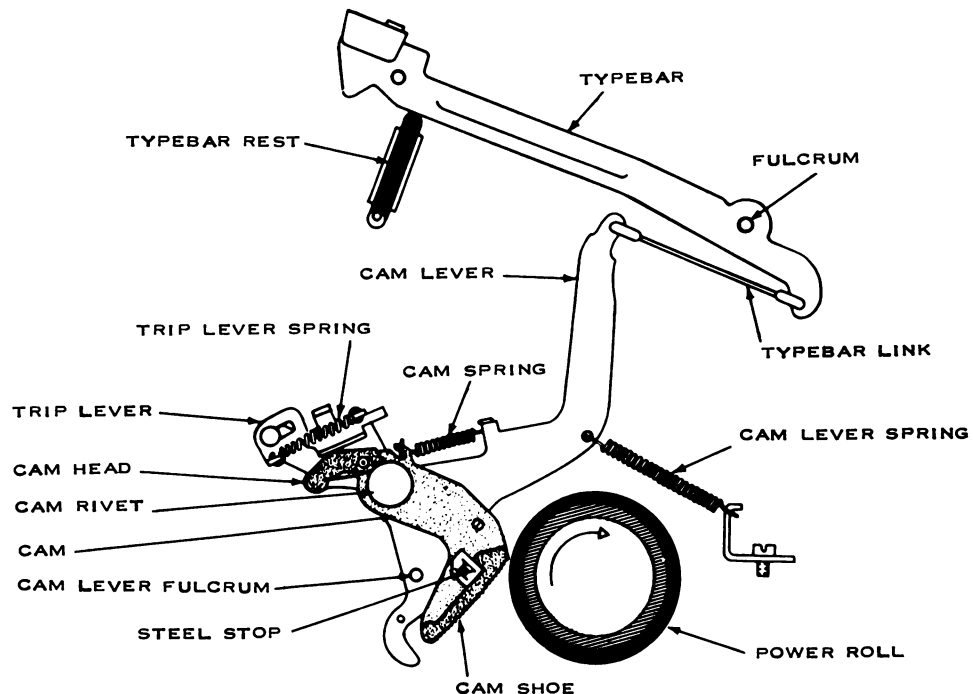
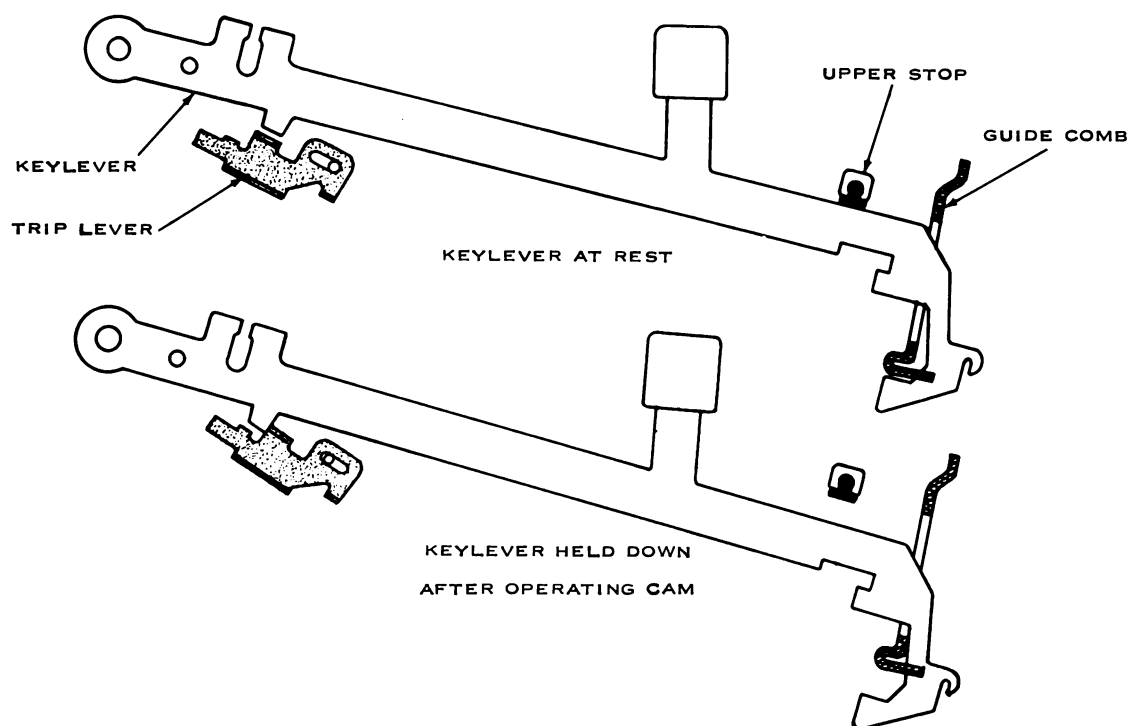


Figure 15-22.—Cam lever assembly and type bar.

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91.11X

Figure 15-23.—Keylever and trip lever action.

The relationship between the type bar, ring, and platen is known as RING AND CYLINDER. This is something important to remember when you adjust the typewriter. Ring and cylinder adjustment is correct when the space between the typeface and the platen (with ribbon and paper in position) is .003 inch. Study figure 15-26.

The IBM electric typewriter has changeable type bars which can be hooked onto the fulcrum wire. Spring tension of the U-bar helps to hold them in position during printing, and a special type bar link with a spring clip is also used on them.

Keylevers

You are aware of the characteristics of keylevers used on manual typewriters, but the keylevers considered here are the repeat and non-repeat types used on the IBM electric machine. A two-piece keylever is used for field installation of a repeat/non-repeat character in any letter position desired.

When a repeat/non-repeat keylever is depressed to the limit in the front guide comb, the rear step on the keylever lug provides a single operation of the cam, as shown in parts A and B of figure 15-27. If the keylever is held down in this position, the rear step on the keylever lug prevents the trip lever from restoring to the normal rest position. Further depression of the keylever is possible because of an enlarged fulcrum hole and the repeat spring. When the fulcrum point of the keylever is lowered, the repeat stop of the trip lug depresses the trip lever and allows repeat action by the cam. If the keylever is held in this position, the trip lever is cammed down by the front step on the keylever lug each time the cam lever assembly restores from a former operation, as illustrated in part C of figure 15-27.

Now that you have studied the parts and mechanisms from a keylever to a type bar, let's see what happens when a key button is depressed.

When a typist depresses a letter key button, the keylever pivots about the fulcrum rod in the keylever bearing support (fig. 15-28), and a lug on the bottom of the keylever contacts the top lug of the cam trip lever. The trip lever is riveted to the cam lever and pivots down against the cam, causing it to engage the power roll. The distance between the toe of the cam and its shoulder rivet is greater than the distance between the heel of the cam and the rivet. This is called the **RISE OF THE CAM**. As the power roll causes the cam to rotate, the rise of the cam forces the cam lever assembly to pivot about its fulcrum (cam lever fulcrum rod). The cam lever action pulls on the type bar link and pivots the type bar on its fulcrum wire, which drives the typeface toward the platen.

Before the typeface reaches the platen, the head of the cam contacts the cam knockout finger, as shown in figure 15-29, which stops the rotation of the cam. The momentum of the type bar, however, continues the motion of the cam lever and the type bar to the platen. The

continued motion of the cam lever releases the nylon cam from the power roll and the cam spring restores the cam to its rest position against the cam lever.

The Escapement

A typewriter carriage moves from right to left under spring tension. The position of the carriage in the IBM electric is controlled by a single pawl (fig. 15-30) engaged in a toothed rack secured to the bottom of the carriage. Operation of the pawl to allow the carriage to move one space at a time is known as **ESCAPEMENT**. The escapement is operated by a type bar moving toward the platen or by the spacebar. Refer to figure 15-30 as you study the escapement.

ESCAPEMENT OPERATION.—When a type bar moves toward the platen, it contacts the U-bar and pushes it rearward. The motion of the U-bar is then transferred to the escapement trip link by an adjusting plate (fig. 15-30).

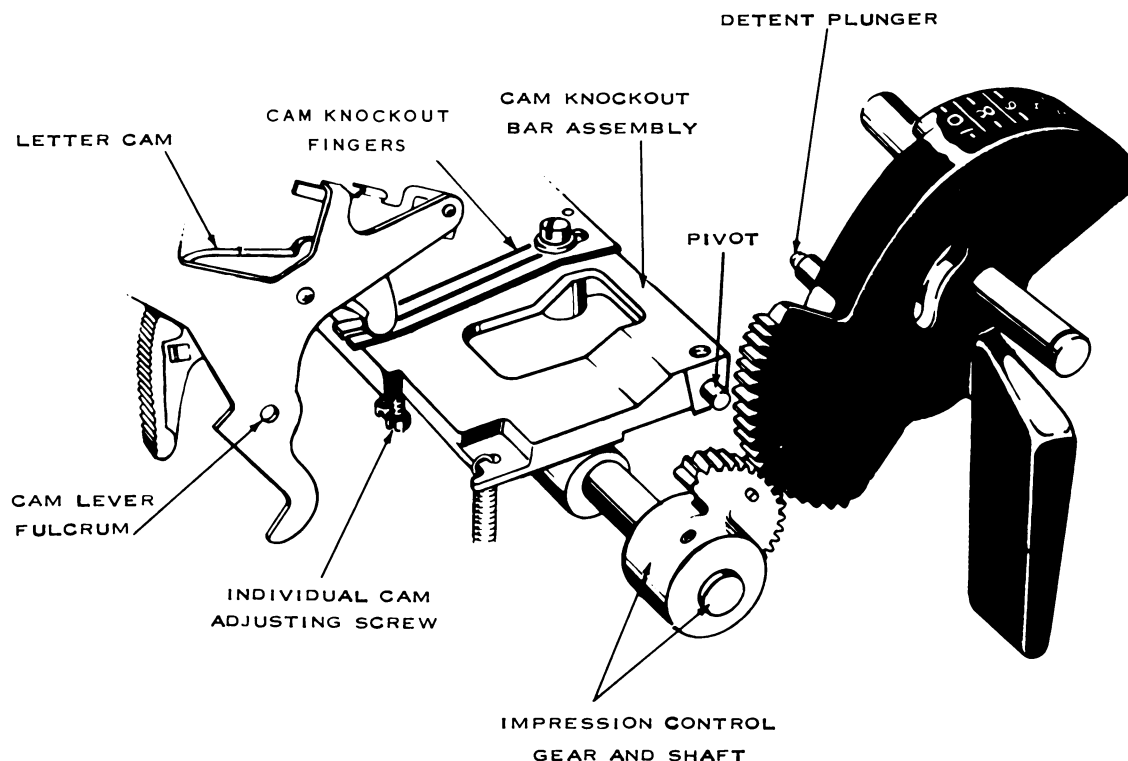


Figure 15-24.—Impression control mechanism.

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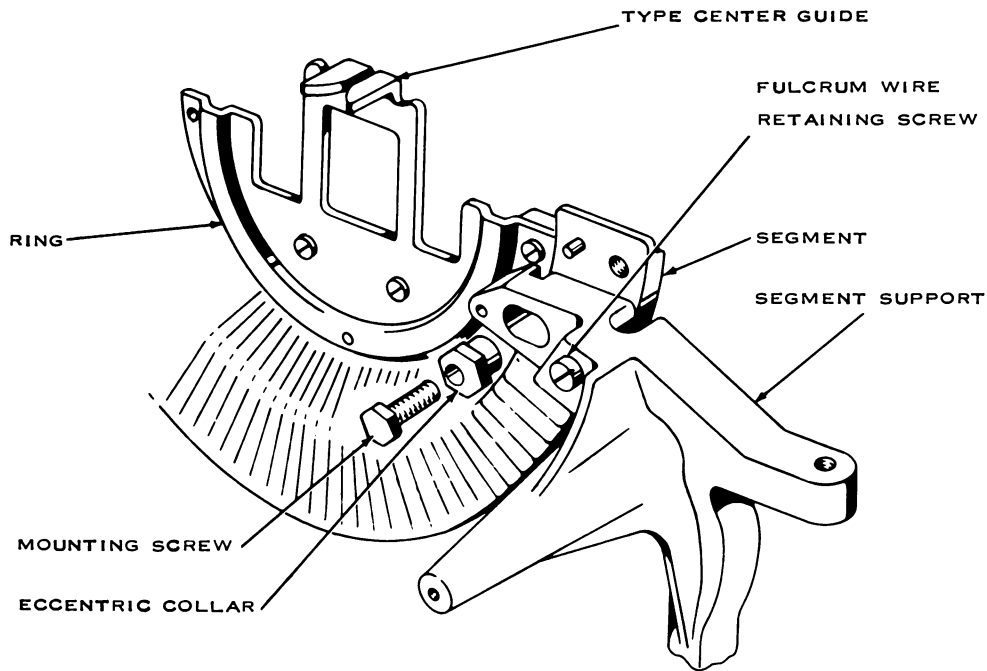


Figure 15-25.—Segment mounting.

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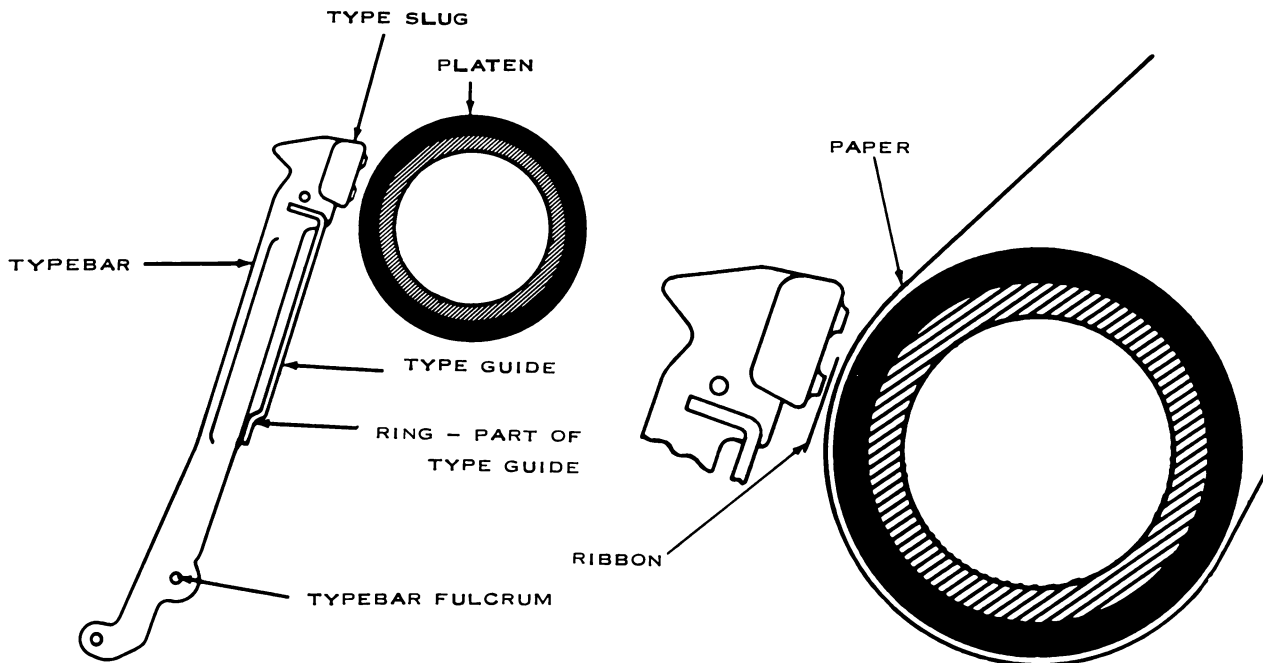
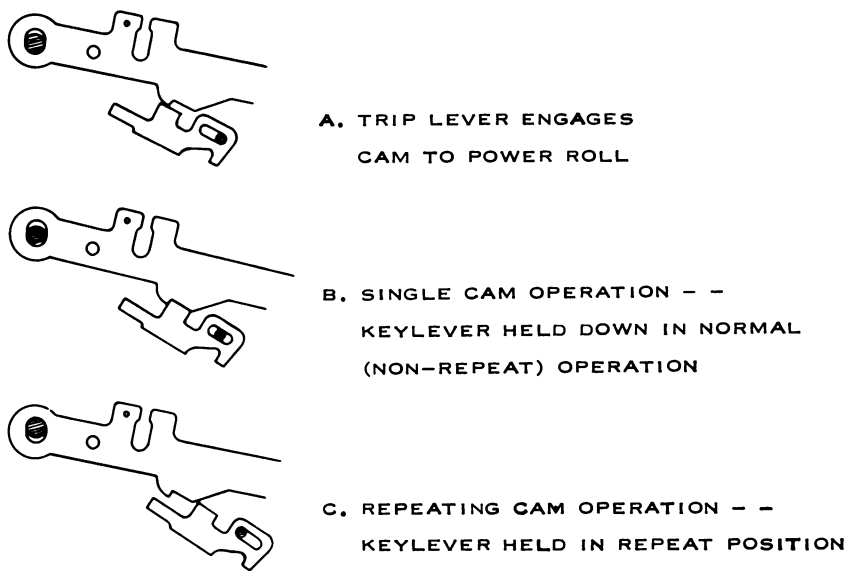


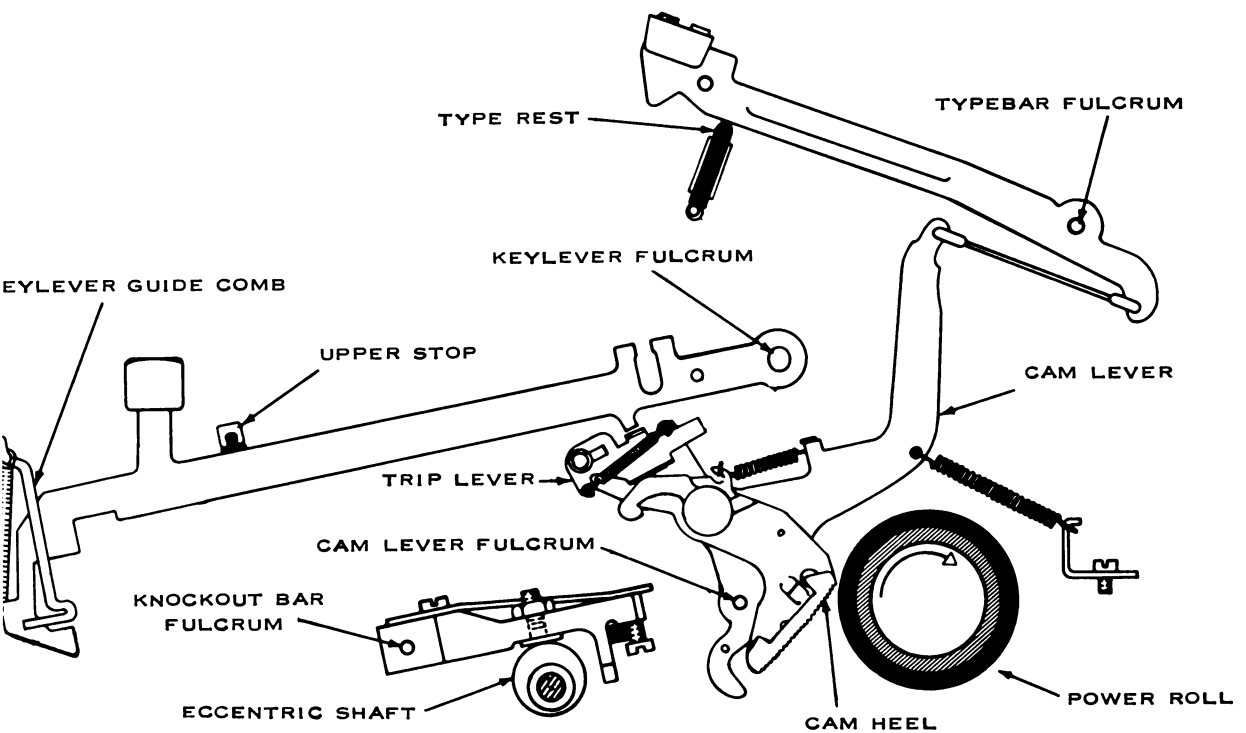
Figure 15-26.—Type bar, ring and cylinder.

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91.15X

Figure 15-27.—Repeat keylever action.



91.16X

Figure 15-28.—Cam and type bar (rest position).

Motion of the trip link rotates the escapement trip lever, causing the top of the lever to move toward the front of the machine. The top of the trip lever pushes on an upright lug of the escapement pawl spacer and pivots the spacer forward. Part of the spacer upright lug is behind the tail of the escapement pawl and carries the tail of the pawl forward. The escapement pawl then pivots enough on its mounting stud to pull the pawl tip out of the escapement rack.

When the escapement pawl tip is free of the rack teeth (fig. 15-31), the escapement pawl

spring pulls it to the right and into the next tooth of the rack. (Note rivet through elongated hole in the pawl.) Because of its relatively heavy mass and inertia, the carriage does not move until the pawl tip is safely positioned on the next rack tooth. As the pawl is pulled to the right, its tail clears the upright lug of the spacer (fig. 15-31). The spacer then continues to move forward until the type bar reaches the platen. A portion of the escapement pawl mounting bracket serves as an overthrow stop to prevent the spacer from getting in front of the pawl tail.

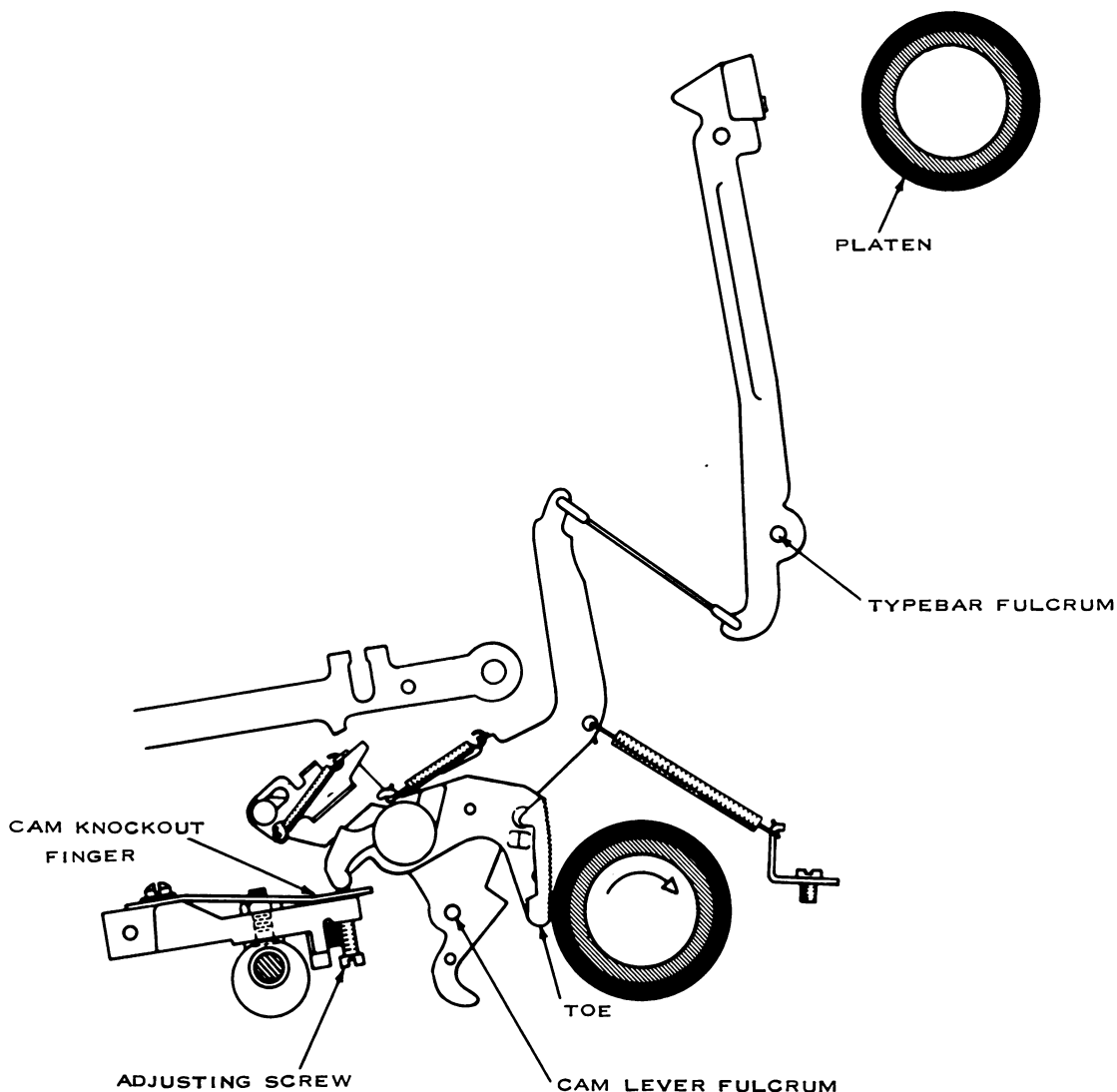


Figure 15-29.—Cam and type bar (knockout position).

91.17X

When the type bar reverses direction after printing, the pawl spacer spring restores the spacer to the rear and behind the pawl tail again.

As the carriage moves to the left under tension of the mainspring, the escapement pawl is pushed to the left by the rack tooth until the right edge of its elongated mounting hole contacts the mounting rivet, in which position it stops and holds the carriage. The tail of the escapement pawl is again in position in front of the upright lug of the spacer—one escapement cycle has been completed. (Note that the carriage moves AFTER the type bar prints.)

ESCAPEMENT PAWL ASSEMBLIES.—Two types of escapement pawl assemblies are used on the C-1 IBM electric typewriter. Machines with 6 $\frac{2}{5}$ and 14 pitch use an escapement pawl with .038" left-to-right motion. This assembly bears no identification mark. Machines with 8, 9, 10, 11, and 12 pitch use an escapement pawl with .058" motion and a pawl spacer with its upright lug located .027" farther to the right.

This assembly, called the **FLOATING PAWL**, is identified by a notch in the front edge of the pawl and also of the spacer. This type of pawl permits greater typing speed without piling, because the parts come into position sooner than in the other pawl assembly.

The floating pawl travels .020" farther to the right after escapement, because of the greater elongation of its mounting hole. The pawl tip, therefore, must be positioned .020" nearer to the next escapement rack tooth when it re-enters the rack.

ESCAPEMENT RACK.—Spacing of teeth on the escapement rack determines the distance the carriage travels on each escapement operation. The number of spaces or typed characters to the inch is known as the **PITCH** of the typewriter. The C-1 machines have 6 $\frac{2}{5}$, 8, 9, 10, 11, 12, and 14 pitch. Pica type is 10 pitch; elite type is 12 pitch.

The escapement rack is screwed and doweled to the bottom of the carriage on all early C-1

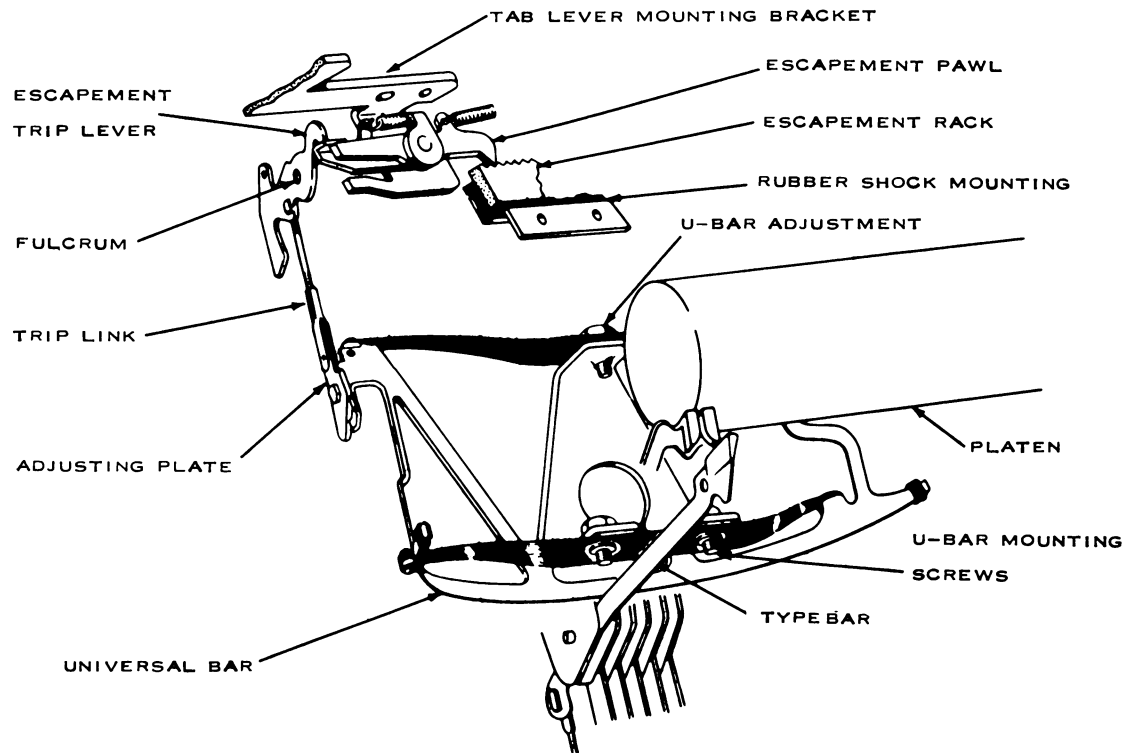


Figure 15-30.—Escapement mechanism (electric typewriter).

91.18X

typewriters, but the racks in later models with 13" and 17" carriages employ a rubber shock mounting which reduces noise (fig. 15-30).

Mainspring

The type of mainspring used on the C-1 typewriter is illustrated in figure 15-32. You learned previously that the function of the mainspring is to provide power to move the carriage when escapement takes place.

The mainspring and holder assembly are mounted to the power frame on a decelerator shaft (fig. 15-32). An ear on the holder contacts a part of the power frame and prevents the assembly from rotating. The drum, which winds the carriage tension tape, also fits on the decelerator shaft and rotates with it. A hook on its hub engages the end of the inner coil of the mainspring. The drum should be rotated to wind the mainspring to proper tension before the carriage tension tape is attached to the end of its outer coil. The other end of the tape is fastened to the right side of the carriage.

Use much care when you remove the mainspring drum from the spring. If it is necessary that you separate the drum from the mainspring and holder assembly, be sure that the spring is completely disengaged from the hook on the drum before you separate them.

Carriage and Rails

The function of the carriage is to support the paper and to carry it to the left and to the right for typing. The carriage consists of two sections, an outer carriage and an inner carriage. The inner carriage supports the platen and feed rolls and is mounted on the outer carriage in a manner which enables a typist to move it from front-to-rear positions by means of the multiple-copy control lever. This arrangement provides RING AND CYLINDER control for the operator. By positioning the copy control lever toward the rear, the operator can get ring and cylinder control best for the number of copies of paper in the machine (originally adjusted for one sheet).

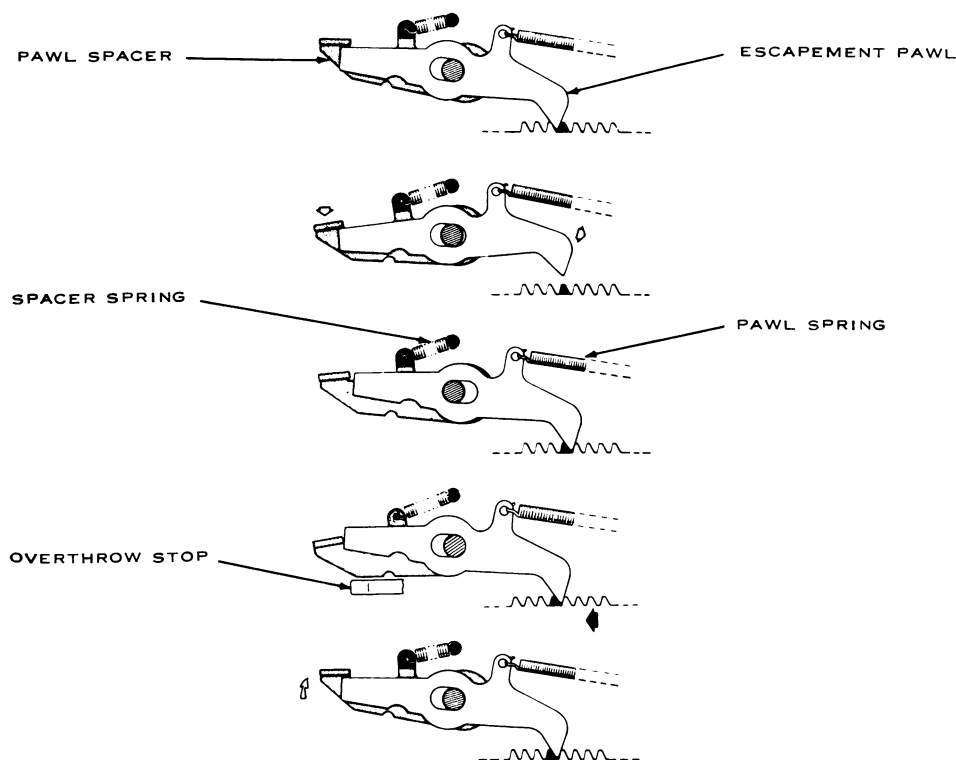


Figure 15-31.—Escapement pawl sequence.

91.19X

The inner carriage (fig. 15-33) consists of right and left platen guide plates connected by the platen guide shaft, the feed roll release cam shaft, and the carriage tie rod. Notches in the rear of the platen guide plates fit on grooved studs riveted to the outer carriage. The left guide plate has an extra bearing point on the outer carriage to provide stability for the line-space mechanism mounted on the guide plate. The paper bail pivot shaft and the front scale are also mounted on the inner carriage, which on late model machines is spring-loaded to the rear.

A resilient nylon washer fitted to each platen guide plate eliminates front-to-rear play in the platen mounting, without adjustments. The washers are so fitted that they are compressed when the platen is installed.

When the multiple-copy control lever mounted on the right platen guide plate is operated, it rotates the platen guide shaft and its eccentric collars. The shaft rotates with the collars; but because it is off center in the collars, it also moves front and rear. This shaft move-

ment causes the entire inner carriage to move forward or backward.

The outer carriage consists of a welded box-type carriage bed with an end plate welded to each end. See figure 15-34. The outer carriage mounts (in addition to the inner carriage) the escapement rack, the margin rack, and the tab rack. The entire assembly rolls on steel rollers between V-shaped rails, as shown in figure 15-35.

Plastic trucks are used to hold the rollers in uniform spacing. Each truck has four rollers which extend through openings in the truck, as illustrated. The positions of these trucks are maintained by star wheels pinned to the trucks. These wheels engage teeth cut into the upper plate of the carriage bed and the lower edge of the rails. Carriage movement rotates the star wheels between the upper and lower rows of teeth, and the star wheels move the truck assemblies with the carriage. In order for a star wheel to mesh equally with the teeth of the carriage and the rail, it must ride slightly high in the truck. For this reason, the star

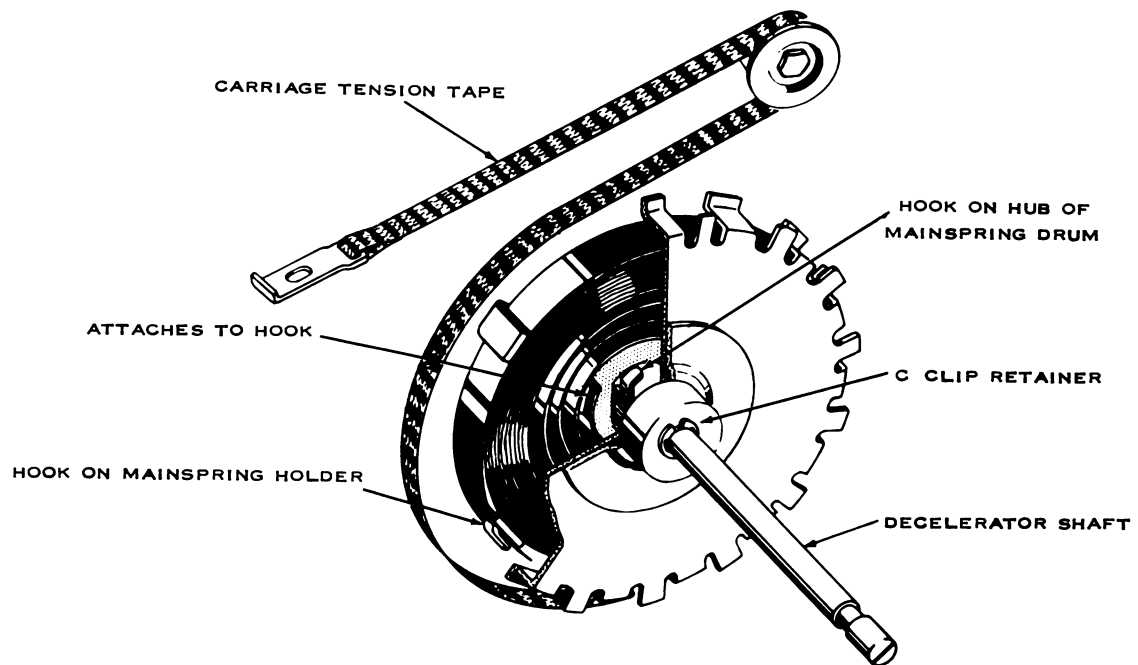


Figure 15-32.—Mainspring, drum and tension tape (rear view).

91.20X

wheel pin is positioned in the truck slightly above center. Proper installation of trucks is most essential, and is indicated by the downward facing of the flat of the lug on one end of the truck. A 13" carriage is supported by 4 truck and roller assemblies. Longer carriages require more assemblies: 6 for 17" carriages, 8 for 20" carriages, 10 for 24" carriages, and 12 for 30" carriages. Be sure to follow the manufacturer's instructions in the technical manual for the machine when you install trucks.

A lug which extends upward from the margin control lever (fig. 15-34) contacts the left-hand carriage endplate and limits travel of the carriage to the right; and a step on the margin re-set lever contacts the right-hand carriage endplate to limit carriage travel to the left.

When a typist depresses the left or right carriage release button, the carriage release lever pushes a carriage U-bar (fig. 15-34) toward the rear of the machine, allowing it to contact a lug on the pawl release lever. The pawl

release lever is mounted on the rear rail by a screw and an eccentric collar, which allows it to pivot. Study figure 15-36. As this lever is pivoted to the rear, it pulls the escapement pawl from the rack to release the carriage.

On 13" carriages, a bracket at the middle supports the carriage U-bar and provides an additional pivot mounting for it (fig. 15-34). The bracket extends upward to support the paper table, and it also has a stop lug to limit rearward movement of the U-bar. A similar support is used on longer carriages, which also bridge over the margin rack to support the margin and tab racks.

The platen is mounted on the outer carriage. Its shaft bushings rest on a flat surface of the outer carriage endplates, and latches close over the top of the bushings. Adjustments to eliminate vertical play of the platen bushings can be made by positioning eccentrics in the latch mountings. When the copy-control lever is operated, the platen bushings slide back and forth between

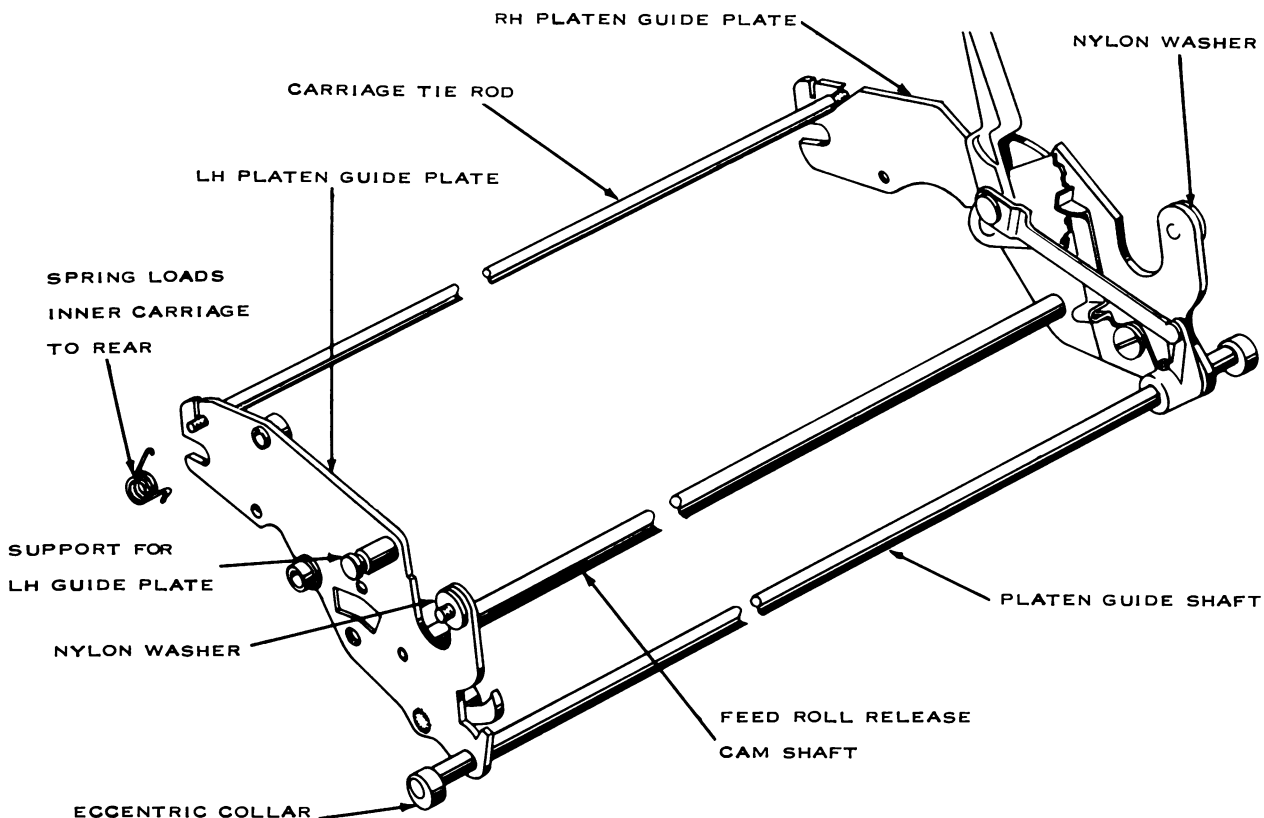


Figure 15-33.—Inner carriage.

91.21X

the parallel surfaces of the latch and carriage endplates.

Paper Feed Mechanism

The function of the paper feed mechanism is to position the paper on successive writing lines. The paper is held against the platen by the pressure of rubber feed rolls, and it rotates with the platen. Study the paper feed mechanism illustrated in figure 15-37. Pay close attention to the nomenclature. You know from previous study how the paper feed mechanism of a standard typewriter functions, so check for similarities and differences in the operation of this feed mechanism.

PAPER FEED ROLLS.—Paper feed rolls (fig. 15-38) are assembled in sets with four feed rolls in each set—two front feed rolls and two rear feed rolls. The number of sets used in a carriage is dependent upon its length. Spacing of sets is controlled by feed roll center supports between them. These supports (fig. 15-39) are

mounted at intervals along the carriage bed for these reasons: (1) to provide support beneath the cradles, (2) to prevent bowing of the paper feed mechanism in the middle, and (3) to provide bearing surface for additional multiple-copy control eccentrics mounted along the platen guide shaft.

Feed rolls are molded on a hub which turns on the feed roll shaft. Two hubs are positioned on each shaft by spring retainer clips, as shown in the illustration. Note the feed roll cradles, pressure levers, and the C clips fitted to the ends of the plastic bushings to hold the pressure levers and cradles together.

FEED ROLL RELEASE ACTION.—Study figure 15-40 to learn how the feed roll release mechanism works. Note in part A of this illustration the position of the feed roll release cam shaft when the feed rolls are holding the paper against the platen. To release the holding action of these feed rolls, the typist must pull the feed roll release lever forward to cause the feed release cam shaft to rotate and lower all the

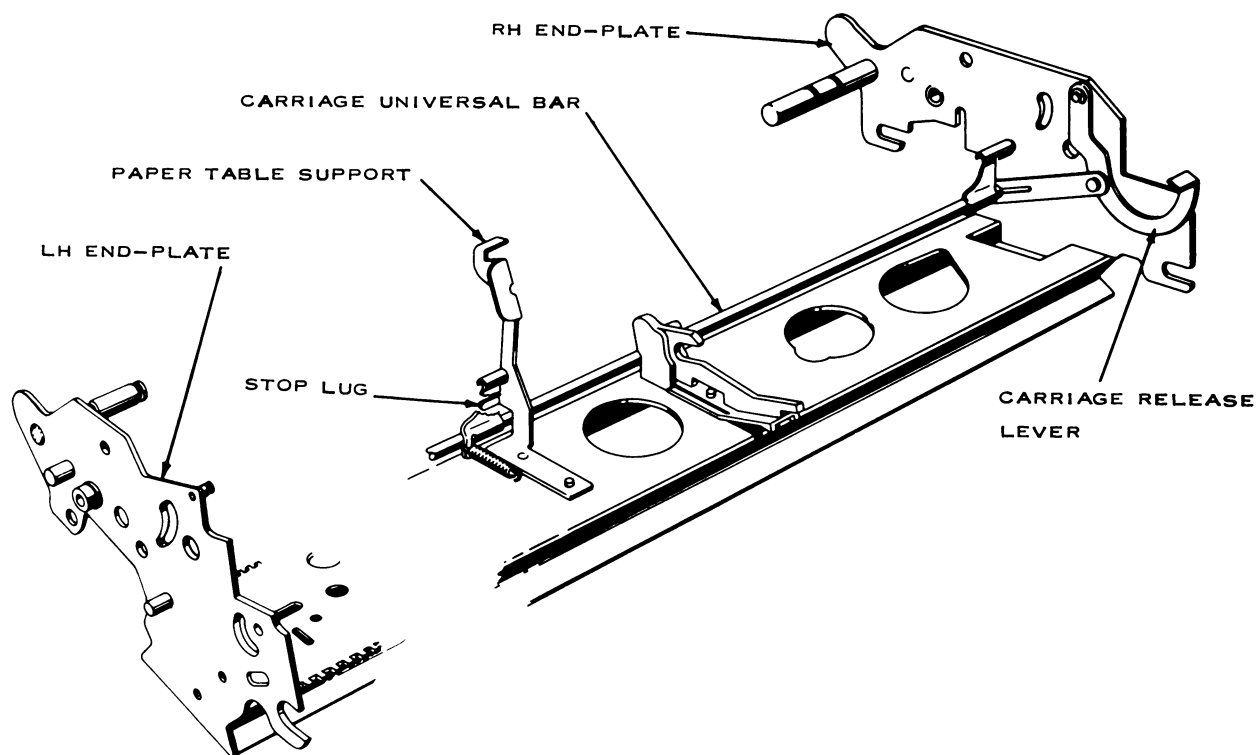
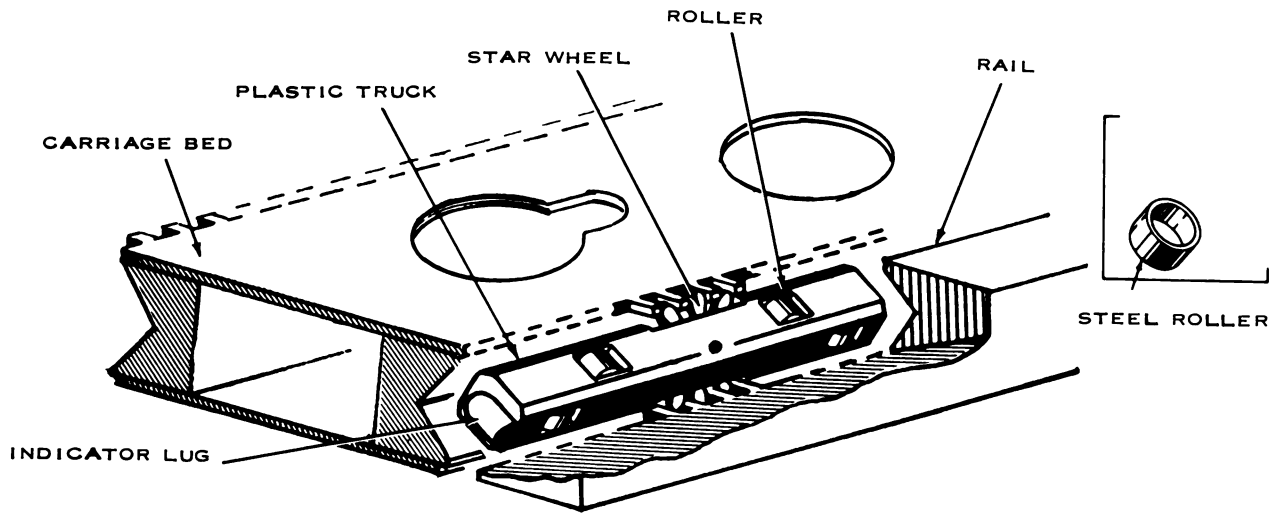


Figure 15-34.—Outer carriage.

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91.23X

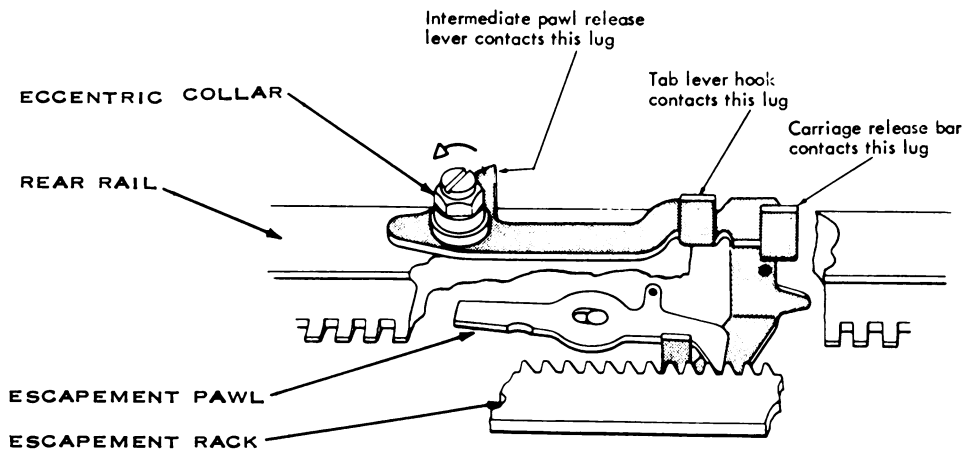
Figure 15-35.—Carriage truck and rollers.

feed rolls simultaneously. This cam shaft extends the full length of the inner carriage and passes through each cradle assembly. Each rear pressure lever rests in a camming slot of the cam shaft (part A, fig. 15-40). The deep part of the slot allows the rear pressure lever to enter the slot far enough for the feed rolls to contact the platen. When the shaft is rotated (part B, fig. 15-40), the pressure levers are forced farther out of the slot and the rear feed rolls are forced away from the platen. An adjusting

plate is secured to the rear pressure lever and moves with it.

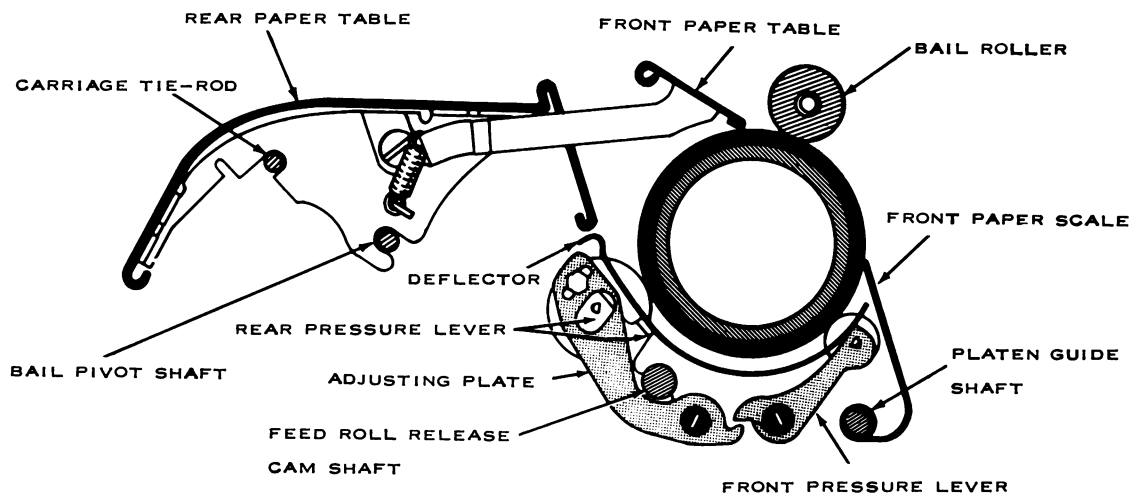
Margin Reset Mechanism

The word MARGIN means the amount of space between typed material (end of line, etc.) and the edge of the paper. Margin stops on a typewriter margin rack can be set at various positions to determine the amount of left-to-right movement of the carriage, which determines the widths of the margins.



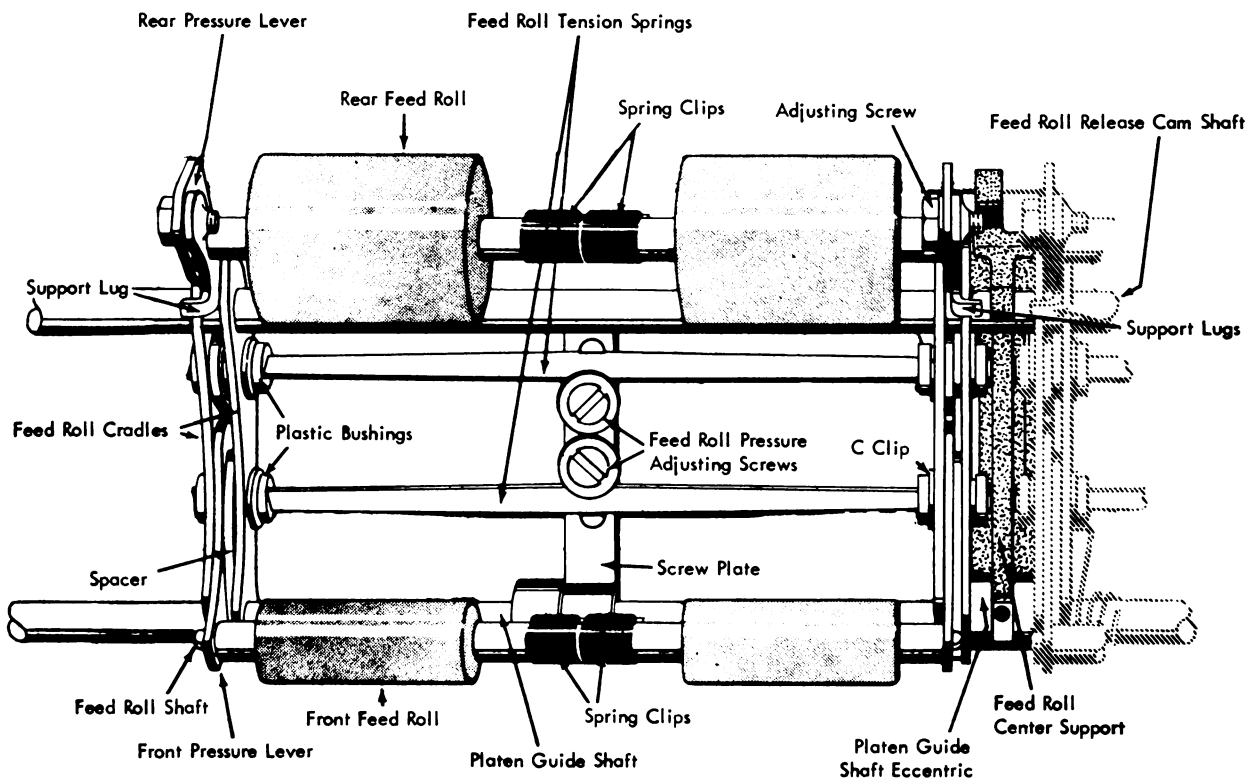
91.24X

Figure 15-36.—Pawl release lever.



91.25X

Figure 15-37.—Paper feed mechanism.



91.26X

Figure 15-38.—Paper feed rolls.

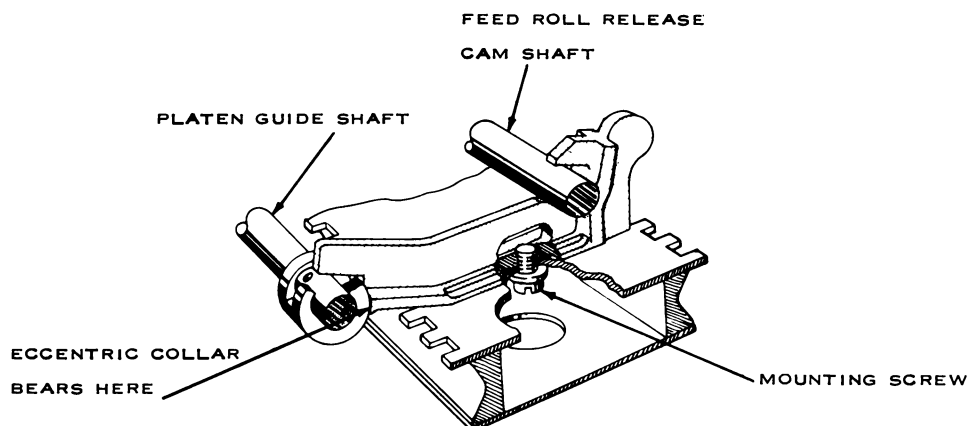


Figure 15-39.—Feed roll center support.

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The operator of a typewriter can relocate margins to any desired point by:

1. Positioning the carriage at its present margin.
2. Depressing the margin reset button (fig. 15-41) and holding it down.
3. Moving the carriage to the desired location.
4. Releasing the margin reset button.

Study figure 15-41 carefully, noting particularly detail A and B, pivot stud for the reset lever, and the mounting stud and fulcrum. When the margin reset button is depressed, the keylever pivots on its mounting stud and (through linkage) rotates the pin on the left end of the margin reset lever downward. This pin contacts the slider and removes the slider pin from the margin rack teeth, allowing free movement of the carriage to the desired position.

Margin Release Mechanism

The margin release mechanism enables an operator to position the carriage beyond the margins without changing the margin stop settings. This mechanism is shown in figure 15-42. Observe the position of the carriage at the LH margin stop, and then note the position of this stop when the operator types through it.

When the margin release keylever button is depressed, the keylever pivots on its fulcrum and raises the tab actuating lever. The tab actuating lever then pivots the tab lever and lowers its right end, which lowers the margin control lever mounted to it, allowing the margin stop to pass over the margin control lever.

Linelock Mechanism

The linelock mechanism serves two purposes: (1) to lock the keyboard when the carriage comes to the end of the line (RH margin), and (2) to lock the keyboard when the switch is turned off.

The locking bar (fig. 15-43) is located beneath the keylevers, which are recessed just above the area contacted by the locking bar, leaving a projecting lug at the bottom. Study the illustration. The locking bar is mounted on a fulcrum wire which extends through the right and left side frames, and it can be pivoted on this wire to block operation of the keylevers. The wire and bar slide to the left and also to the right, as well, pivot forward and backward. The wire is spring-loaded to the right and to the rear. A bushing on the right end of the wire contacts a camming surface on the side of the switch lever, which provides the right-to-left action of the locking bar.

A push rod (illustrated) on the left side of the locking bar connects with linkage on the rear rail and transfers carriage movement from the margin control lever to pivot the locking bar when the carriage reaches the RH margin. The switch lever also pivots the locking bar when it is rotated to the OFF position. Study the illustration carefully. Note the carriage return lock.

A separate section of the locking bar locks ONLY the carriage return keylever. It pivots independently on the fulcrum wire and allows operation of the carriage return mechanism to

return the carriage from the RH margin. The carriage return keylever is locked only when the switch is off. A lug on the carriage return lock extends through the right side frame, in which position the switch lever contacts it.

Motion of the carriage pivots the linelock lever, mounted to a stud on the tab lever mounting bracket. A wire link connects the lower end of the linelock lever to a bellcrank mounted on the rail brace support. The bell-

crank is connected to the linelock push rod, which extends to a point just behind a lug on the left end of the linelock bar.

As the carriage reaches the RH margin, the RH margin stop moves the margin control lever to the left. (Note elongated holes in this lever.) This movement rotates the linelock lever and, through linkage, pushes the push rod toward the front of the machine, where the rod contacts the lug on the linelock bar and rotates

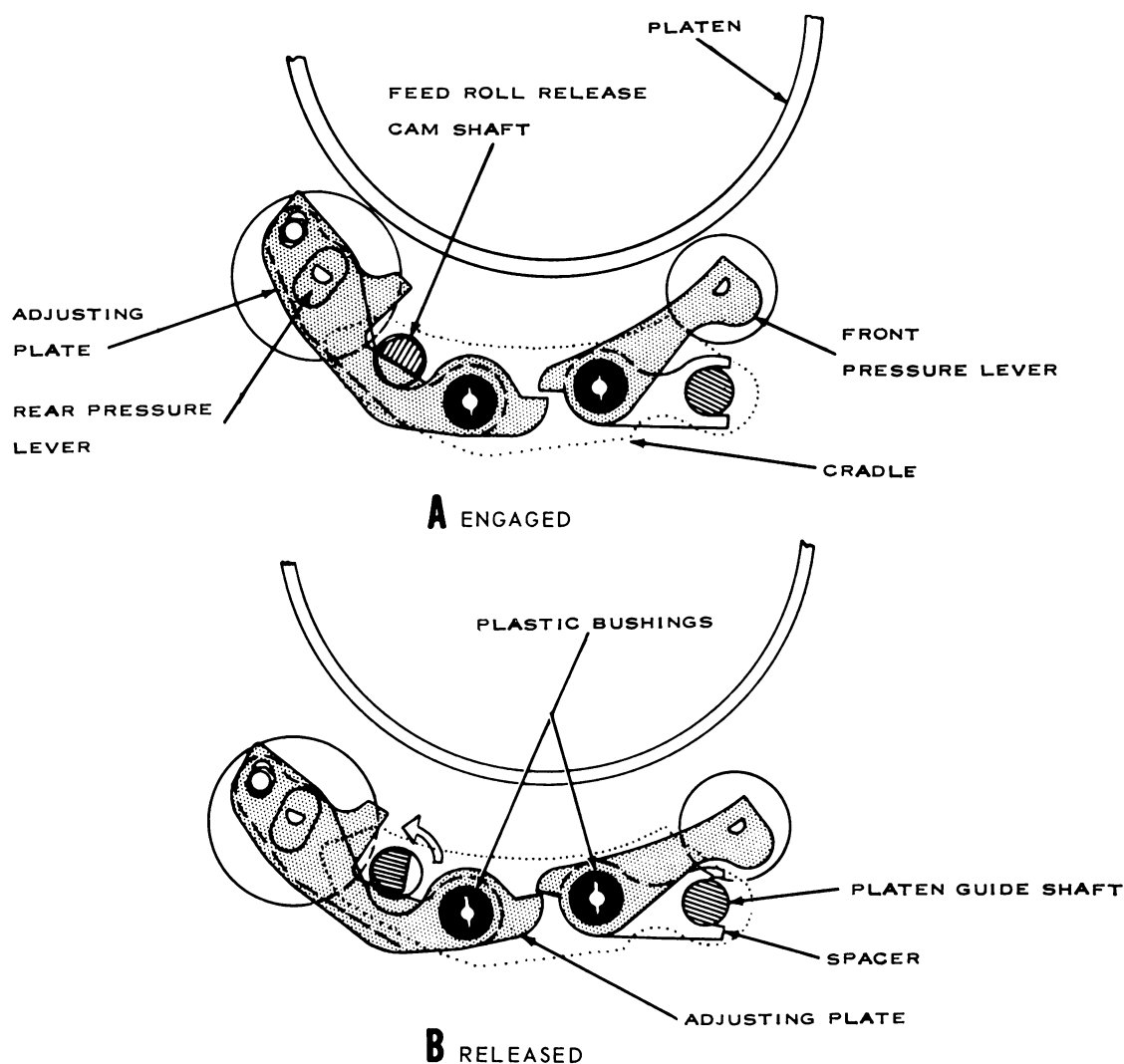


Figure 15-40.—Feed roll release action.

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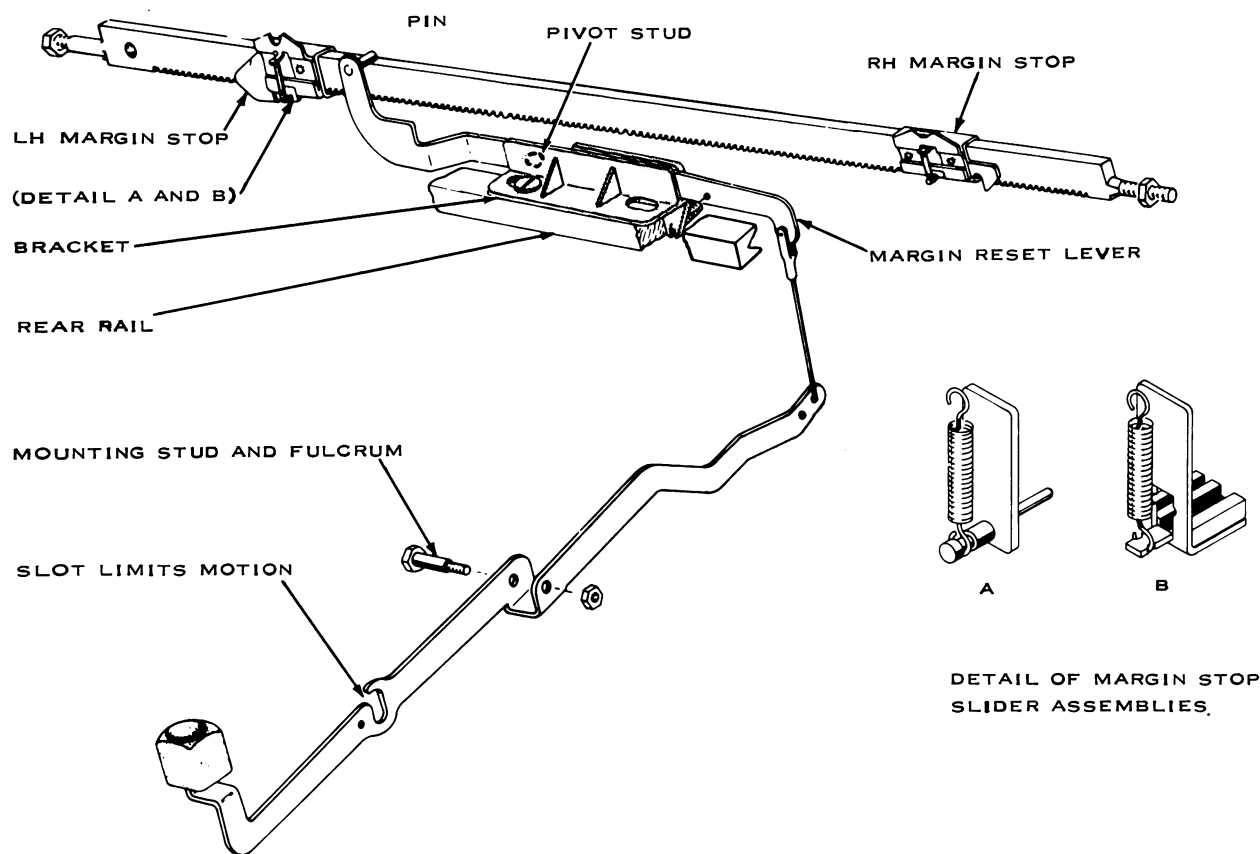


Figure 15-41.—Margin reset mechanism.

91.29X

the bar under the keylevers to prevent further keylever operation. As the carriage is moved away from the RH margin, spring action on the linelock lever and the restoring spring of the locking bar restore the linelock push rod to the rear of the machine.

When the switch is turned off, its camming surface forces the linelock bar to the left. This action positions a locking lug in line with the backspace and spacebar keylevers. The switch motion also pivots the carriage return lock forward against the linelock bar, and this motion pivots the linelock bar forward under the keylevers. When the switch is off, all keys except the shift key and the spacebar are locked.

Functional Cams

The spacebar, carriage return, tab, backspace, shift, and ribbon feed constitute the

service mechanisms of a typewriter. The motion required to operate these mechanisms in an electric typewriter is obtained through metal FUNCTIONAL CAMS. Some of these cams have single lobes and some have double lobes. Cams with single lobes rotate 360° for each operation, to provide a great amount of motion to the mechanism. Double-lobed cams, on the other hand, provide less motion but faster action by rotating only 180° for each position.

Double-lobed cams (fig. 15-44) located on the left side of the machine are used to operate the spacebar, tab, and ribbon feed mechanisms. Single-lobed cams (fig. 15-45) located on the right side of the machine are used for the carriage return and backspace mechanisms. The shift cam, illustrated in figure 15-46, on the right side, is a special double-lobed cam which is also double acting.

All functional cams but the ribbon cam are mounted on short fulcrum rods at either side of the cam lever bearing support. The LF fulcrum rod has a C clip fitted over a groove in the rod. This clip is positioned in an opening of the cam bearing support casting and prevents the fulcrum rod from working out of the support (fig. 15-7). The RH fulcrum rod is held in position in the cam bearing support by a retainer on the right side frame which fits into a groove at the end of the rod. The ribbon cam is mounted on a separate pivot stud screwed into left sideframe.

Adjustable stops position each cam in its rest position, to maintain a clearance between the low point of the cam and the power roll.

Protrusions on both sides of a cam help to activate and control it. A spring finger, for example, bears against a protrusion on one side of a cam to rotate it into the power roll when the cam is released. See figure 15-47. A lug (part of the body) extends out from the other side of the cam (fig. 15-48) as a control point for the cam release lever to engage and hold

the cam from the power roll, or release it into the power roll for operation.

A cam release link (fig. 15-44) from the keylever pivots the cam release lever on the cam frame. The release lever has two lugs slightly offset from each other (fig. 15-48), one slightly behind the other and farther out from the center of the cam. The forward lug is called the primary lug; the other one is the non-repeat lug. The release lever primary lug holds the cam lug when all parts are at rest. A depressed keylever pivots the release lever toward the center of the cam (opposite for ribbon cam release lever) and releases the cam into the power roll. After the cam rotates over its high point, with the keylever depressed, the non-repeat lug catches the cam lug. As the keylever is released, the non-repeat lug pivots away from the cam and releases the cam lug to the primary lug of the release lever. This action resets the cam and it is then ready for another operation.

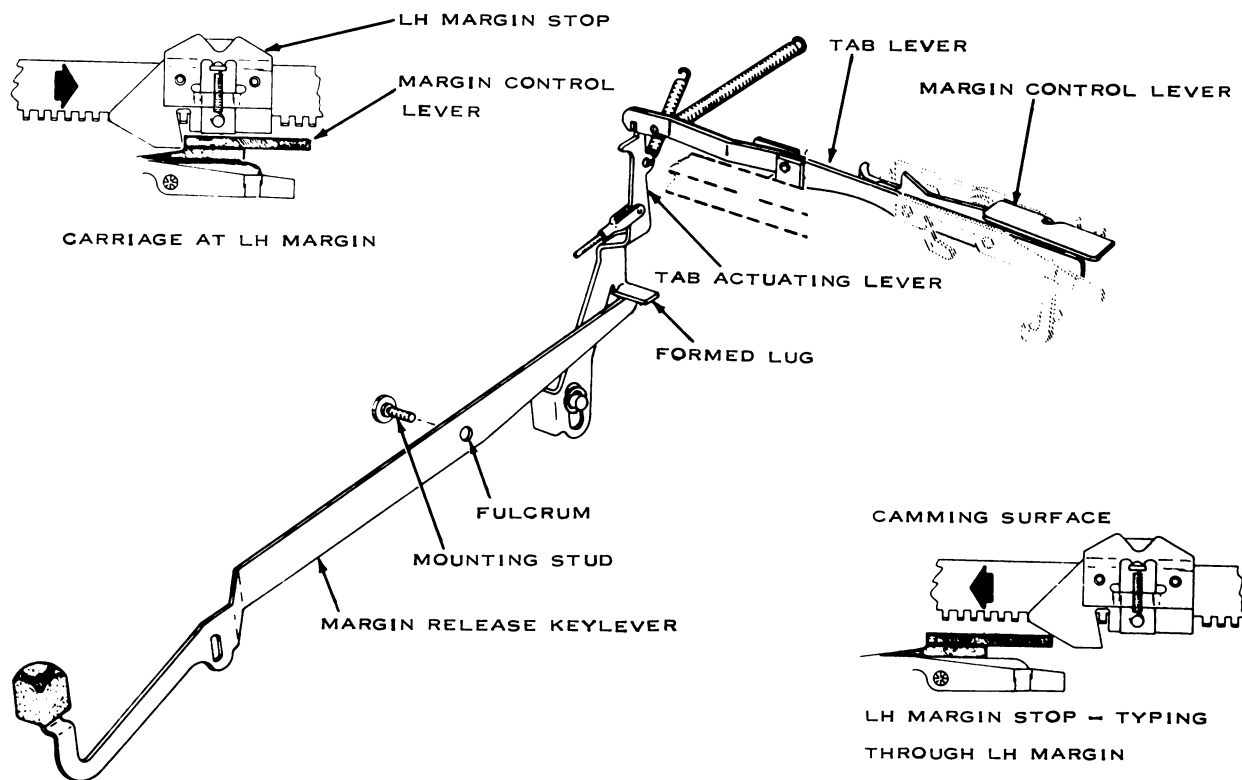
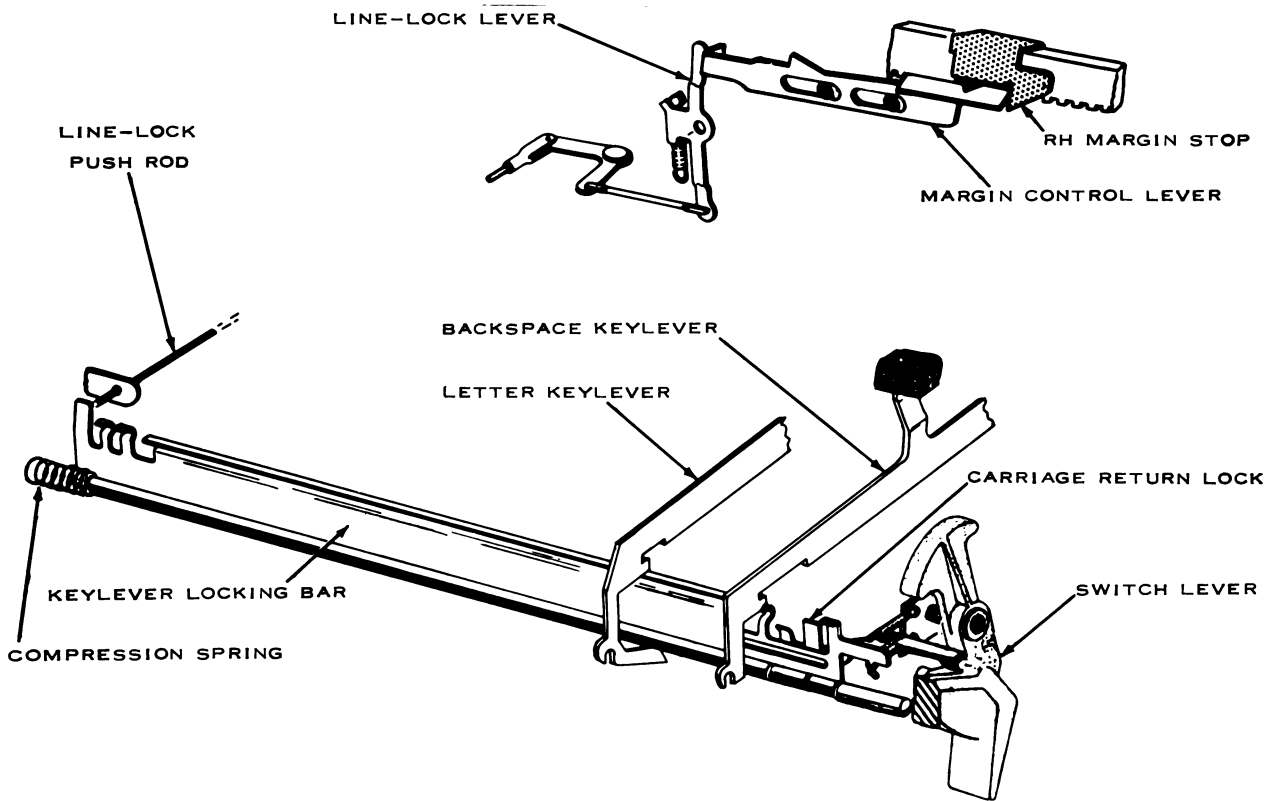


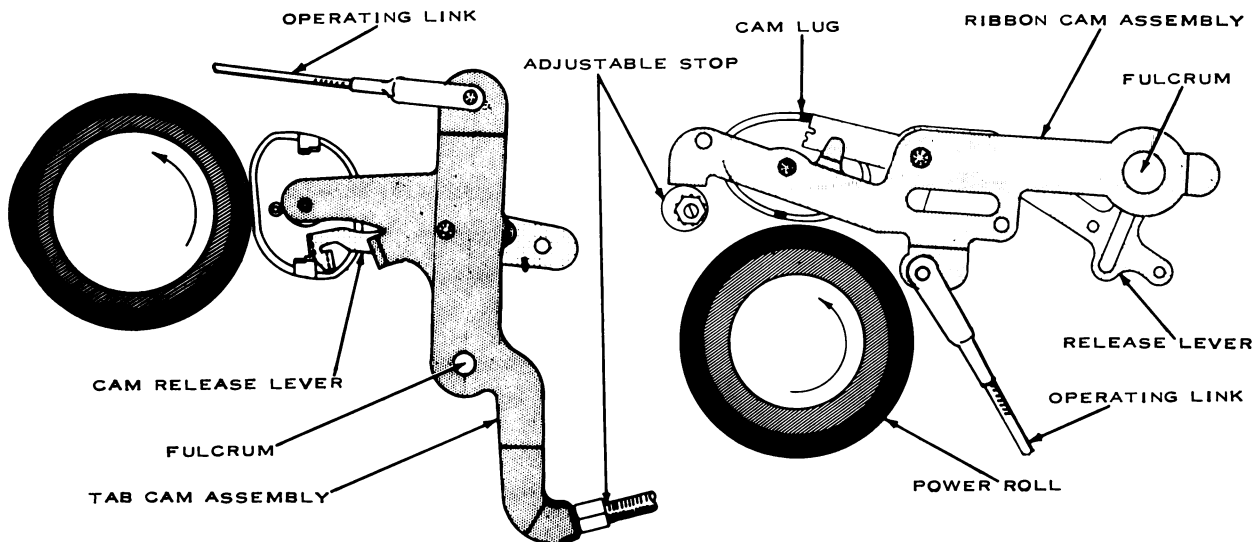
Figure 15-42.—Margin release mechanism.

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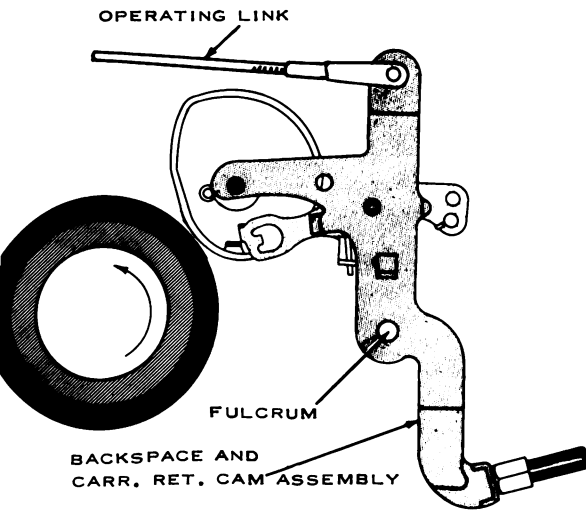
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Figure 15-43.—Linelock mechanism.



91.32X

Figure 15-44.—Double-lobed cams.

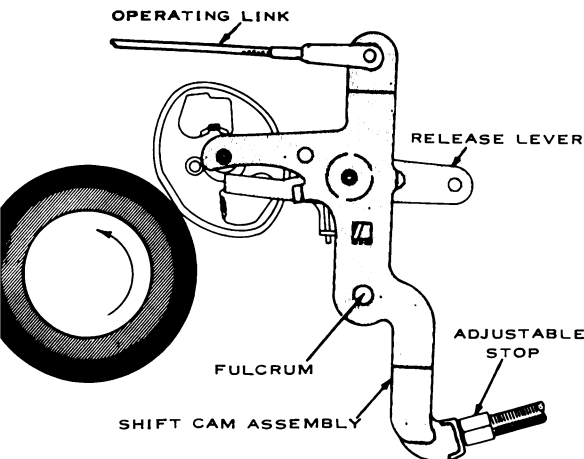


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Figure 15-45.—Single-lobed cam.

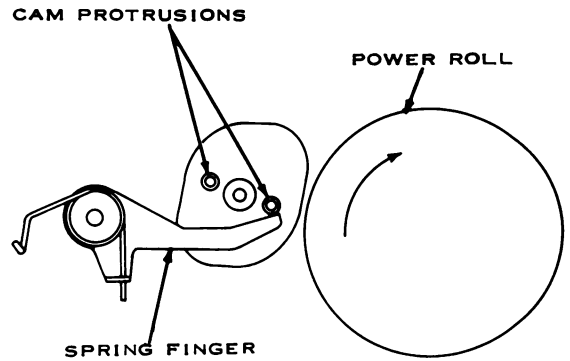
A repeat feature is provided by a different type of cam release lever which pivots the non-repeat lug of the release lever farther toward the center of the cam and out of the path of the lug on the cam.

Because of special requirements of the shift mechanism, the shift cam is constructed differently from other double-lobed cams. See figure 15-49. This cam rotates $1/2$ revolution when the keylever is depressed and completes the revolution when the keylever is released.



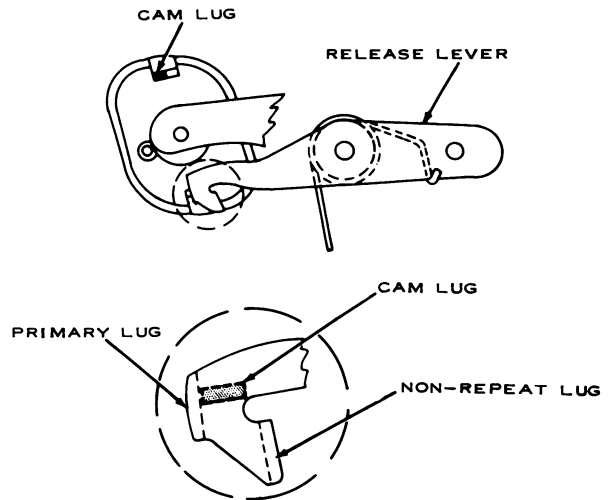
91.34X

Figure 15-46.—Double-lobed shift cam.



91.35X

Figure 15-47.—Cam spring finger.



91.36X

Figure 15-48.—Cam release lever (non-repeating).

The shift cam release lever has only one lug. The shift cam has two lugs at 180° but one is closer to the center than the other (fig. 15-49). Hence, when the release lever releases the other lug, the release lever moves into the path of the inner lug to stop the cam at $1/2$ revolution. When the release lever releases the inner lug, it moves into the path of the outer lug to stop it at the completion of the revolution.

As the cam rotates over its high point, it causes the cam to pivot on its fulcrum. An operating link attached to the cam frame delivers the motion to the service mechanism involved.

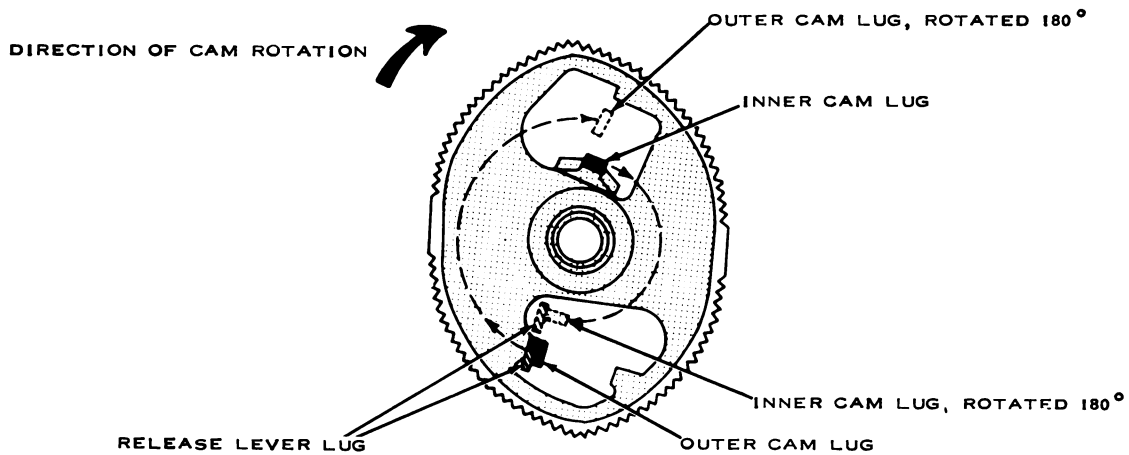


Figure 15-49.—Shift cam.

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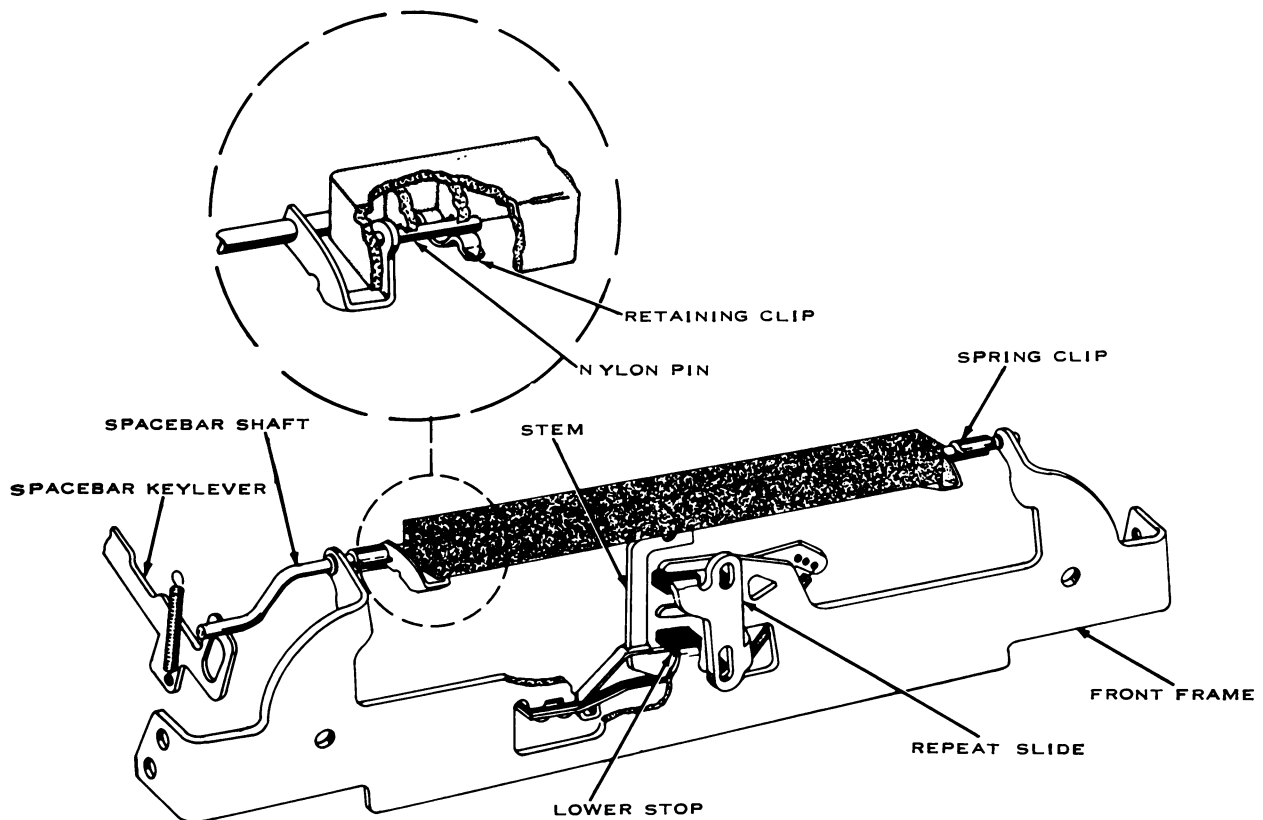
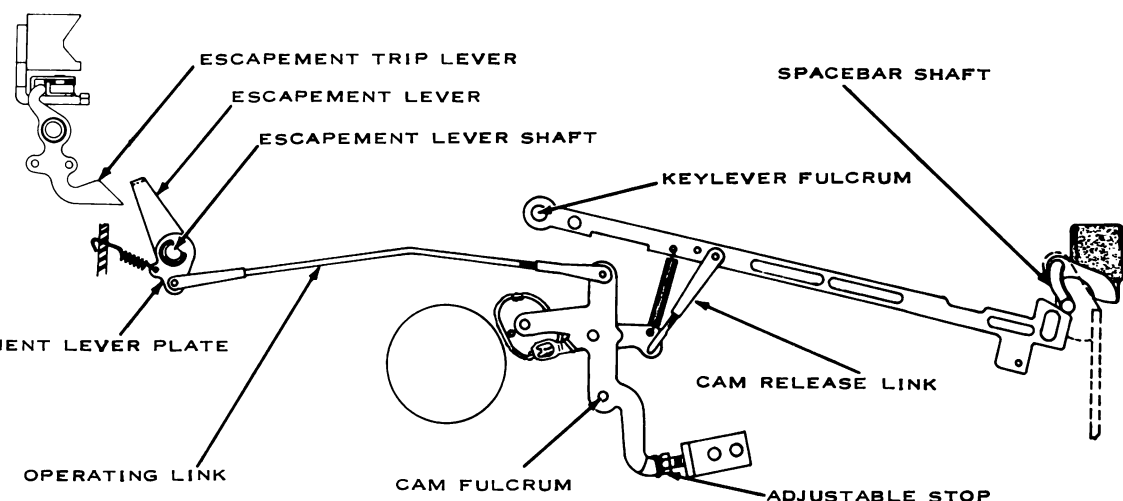


Figure 15-50.—Spacebar and repeat slide stop.

91.38X



91.39X

Figure 15-51.—Spacebar mechanism (electric typewriter).

ating linkage is restored to the rest by a spring attached to some part in e. This spring also loads the cam into roll to ensure that it rotates with the l.

Mechanism

spacebar mechanism enables an opera- the escapement without printing. The has controlled repeat operation. Study 50. Note magnified portion (circle) of the bar.

spacebar is mounted on brackets on the shaft with nylon pins and barbed re- os. The bar has a stem which extends in its center through a guide to keep it in the mounting. The bottom of the stem also contacts an adjustable flat which provides restoring tension for the and shaft assembly. A rubber stop on frame engages the lower hooked the stem and determines the upper ition of the spacebar. The downward of the spacebar is limited to a ce operation by another rubber stop tacts the upper portion of the space- This stop is mounted on the repeat d in the UP position by a spring. pressure must be applied in order s the slide stop against the spring for repeat spacebar operation.

When depressed, the spacebar mechanism pivots the spacebar shaft mounted on the front frame. The shaft depresses the keylever on the left side of the machine (fig. 15-51), which moves the cam release link down and pivots the cam release lever to release the spacebar cam lobe into the power roll. Note fulcrum point of the cam. As the cam lobe rotates, the cam frame pivots toward the front of the machine, pulling with it an operating link secured to its top and to the bottom of the escapement lever plate (fig. 15-51). Forward movement of the operating link rotates the escapement lever plate and the escapement lever shaft to which it is mounted. The escapement lever shaft extends through the power frame and has an escapement lever attached to its right end. Rotation of this shaft causes the escapement lever to contact the escapement trip lever, causing it to pivot about its mounting on the left rail brace and push the escapement pawl spacer forward into contact with the escapement pawl tail. This action trips the escapement pawl from the rack as the cam reaches its high point. A spring on the escapement lever plate restores the linkage and cam to the rest position.

A typist can obtain repeat action by depressing the spacebar beyond the normal depth for single space operation. Depth for single spacing is determined by contact of the stem with the spring-loaded rubber stop on the repeat slide (fig. 15-52). Additional pressure is

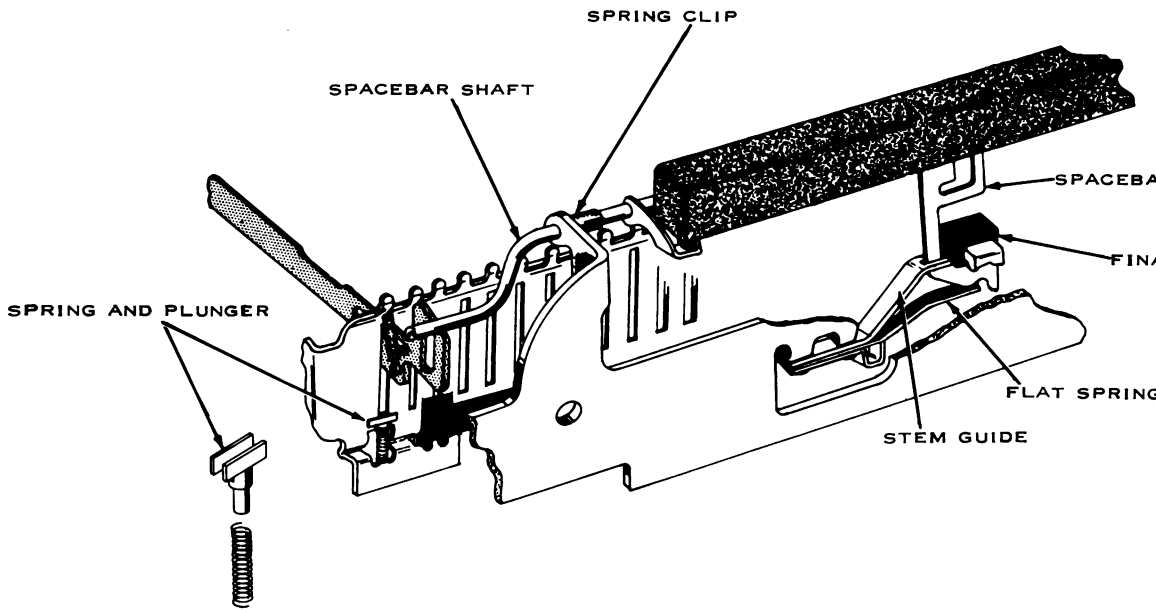


Figure 15-52.—Spacebar, spring and plunger.

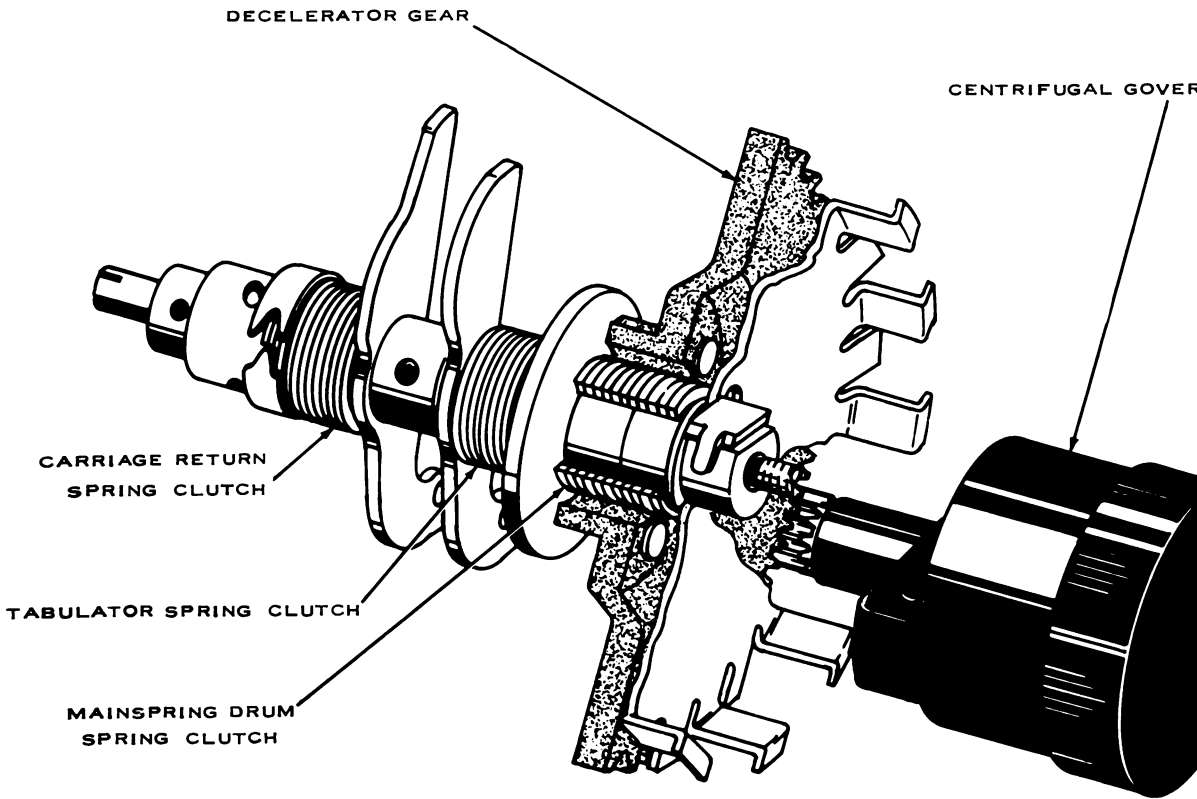


Figure 15-53.—Decelerator and centrifugal governor.

required to overcome spring tension which holds the repeat slide up. Spring tension is adjustable to suit individual touch. Depression of the spacebar and the repeat slide causes the cam release lever to pivot out of the path of the cam lug, allowing the cam to rotate continuously and trip the escapement every time it rotates over its high point (until spacebar is released). (Some C-1 typewriters use a spring-loaded plunger in the keylever guide comb to control repeat operation.)

Decelerator and Centrifugal Governor

Deceleration is the absorption of carriage movement energy over a timed interval. On the C-1 machine, the decelerator and centrifugal governor absorb 85 percent of the shock of carriage landing on tab and carriage return. On tabulation, the time interval is determined by the tab check lever movement. On carriage return, the time interval is determined by the margin control lever movement.

The deceleration mechanism transfers the energy of carriage movement to the centrifugal governor. Study this mechanism in figure 15-53 (centrifugal governor attached). It has three spring clutches which individually drive the decelerator gear, which drives the centrifugal governor.

The centrifugal governor is part of the decelerator mechanism and controls the main-spring to limit the speed of the carriage during tabulation. The decelerator also operates the governor as a brake to ease carriage landings on tabulation and during carriage return. The principle of operation of the centrifugal governor is: AN ACTION WHICH ROTATES THE GOVERNOR PRODUCES A REACTION FROM THE GOVERNOR WHICH RESISTS ROTATION. This reaction is produced in the manner explained in the following paragraphs. Study figure 15-54 as you read the discussion.

The governor has two arms mounted on a disk rotated by a shaft and gear. A pinion gear on the shaft meshes with the large decelerator

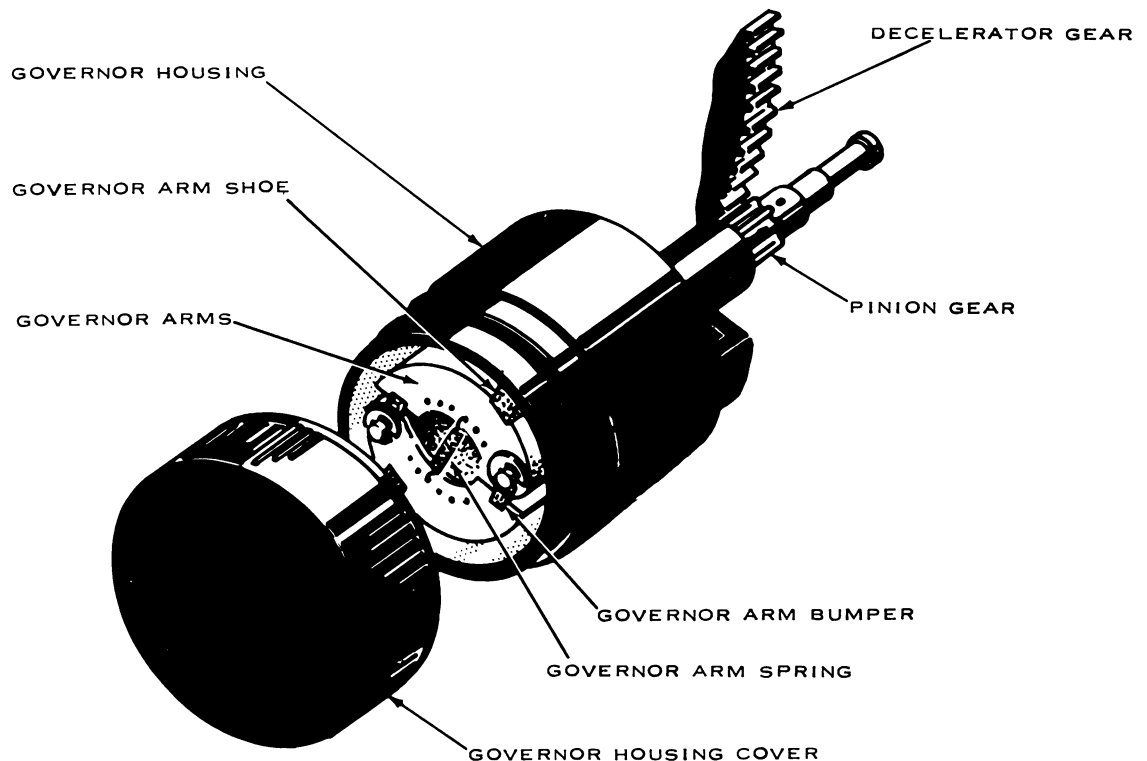


Figure 15-54.—Centrifugal governor mechanism.

91.42X

gear (fig. 15-54). The arms are mounted on pivots and are held toward the center of the governor by a spring which connects one arm to the other. As the shaft rotates at increasing speed, centrifugal force develops and causes the arms to pivot outward, overcoming spring tension. This action forces the oiled, felt brake shoes on the arms against the plastic governor housing. Friction developed between the brake shoes and the housing slows down the speed of revolution until the centrifugal force is diminished. When the centrifugal force becomes less than the tension of the spring between the arms, the spring pulls the arms away from the housing. Then, without hindrance from friction, the speed of the governor can again increase until centrifugal force overcomes spring tension and drives the brake shoes against the housing.

The centrifugal governor does not react until a certain SPEED is attained; and for this reason uniform speed of the carriage from right to left positions (regardless of the difference in carriage tension as the mainspring unwinds) is always maintained. Carriage speed on tabulation is adjusted to equal the speed of carriage return.

Force of the center spring determines how fast the governor rotates before it acts to reduce the speed of rotation. Effective force of this spring can be controlled by the position at which it is attached to the arms. (Note holes.) If the spring is attached farther away from the pivot points of the arms, its effective force is increased; and the governor must then be rotated at a higher speed to develop enough centrifugal force to overcome the spring force.

TAB DECELERATION.—Carriage movement left or right causes rotation of the mainspring drum. Mainspring tension provides carriage movement to the left for tabulation. The mainspring rotates the drum, which winds the carriage tension tape and pulls the carriage. This direction of drum rotation causes the mainspring clutch to drive and rotate the decelerator gear and the centrifugal governor. In this manner, power of the mainspring is controlled to limit carriage speed during tabulation.

Carriage movement to the right opens the spring clutch and causes it to slip. Movement in this direction also pulls tension tape off the drum and rotates the drum against the force of the mainspring. During normal typing, the mainspring drum (rotated by mainspring tension) moves the carriage to the left, the same direc-

tion as during tabulation. The mainspring drum clutch transfers this rotation to the decelerator gear assembly and causes the centrifugal governor to turn; but the speed of carriage movement during normal typing does not rotate the centrifugal governor fast enough to cause the governor arms to contact the housing.

Motion to operate the tab decelerator comes from the tab check lever, shown in figure 15-55.

When the tab mechanism is operated, the tab check lever moves to the right to meet the tab set stop on the carriage. As the tab stop contacts the check lever and pushes it back (elongated holes), it operates the decelerator. A link from the check lever connects to a bellcrank which has a roller on the end of its other arm. This roller is in contact with the tab decelerator arm, and it rides down the cam surface of the tab decelerator arm when the tab check lever is in motion. Movement of the tab decelerator arm by the roller causes the spring clutch to drive the decelerator gear and centrifugal governor. Reaction by the governor causes the decelerator arm to resist rotation, and this resistance is transmitted back through the bellcrank and check lever. As the check lever offers increasing resistance to the tab stop on the carriage, the speed of carriage travel is decelerated.

CARRIAGE RETURN DECELERATION.—

Motion to operate the carriage return decelerator comes from the margin control lever. As the carriage approaches the left margin, the margin stop contacts the margin control lever and pushes it to the right. This action is transferred through the margin control bellcrank (fig. 15-56) to the carriage return decelerator bellcrank. Study figure 15-56 carefully.

The roller on the decelerator bellcrank is in contact with the carriage return decelerator arm, and motion from the margin control lever causes the roller to ride down the cam surface of the decelerator arm and rotate the arm about the decelerator shaft. Rotation of the decelerator arm causes the carriage return spring clutch to drive the decelerator gear and centrifugal governor. The governor reacts to resist the force acting upon it, and this resistance is transmitted back to the margin control lever, causing it to resist the margin stop on the carriage and decelerate the speed of carriage travel.

The stress created during carriage return deceleration is much greater than stress produced during tabulation. Carriage return deceleration starts the centrifugal governor rotating

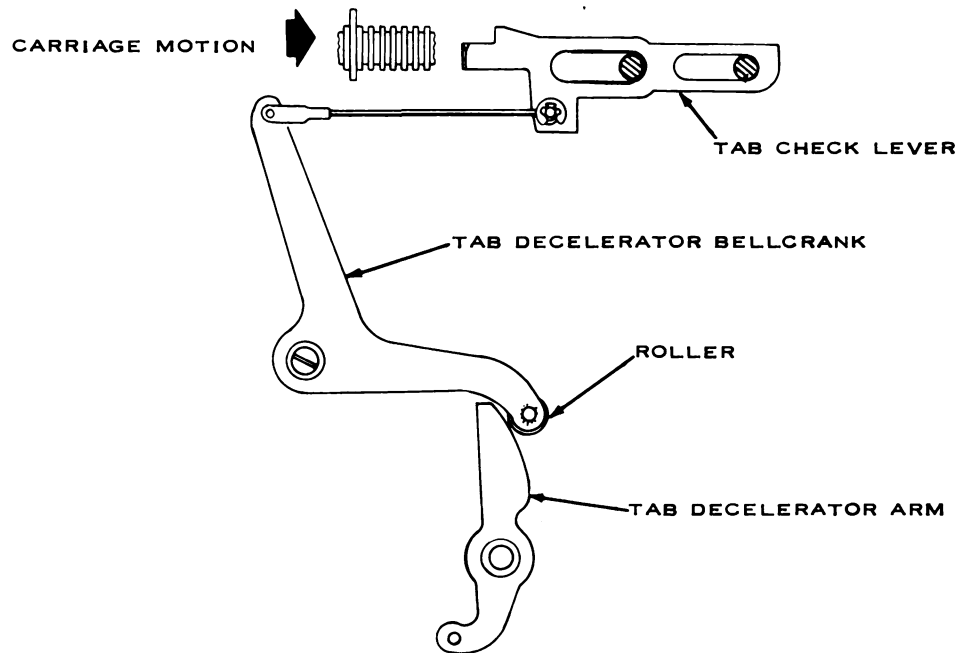


Figure 15-55.—Tab deceleration (rear view).

91.43X

from a stationary condition, so the inertia to be overcome is much greater than during tabulation, when the governor is already rotating before deceleration begins.

The amount of tabulation obtained on carriage return and tabulation depends upon three factors:

1. Position of the center spring attachment on the centrifugal governor arms. When the

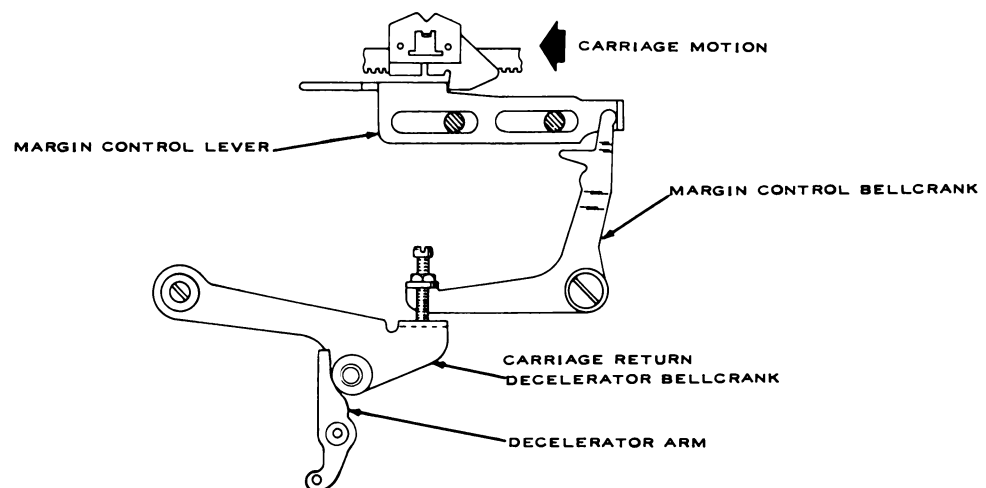


Figure 15-56.—Carriage return deceleration (rear view).

91.44X

spring is moved closer to the pivot point, the decelerator operates sooner and with greater force exerted by the brake shoes.

2. The curve in the camming surface of the decelerator arms. The curve affects the rate of change in the centrifugal governor speed, and it is so designed to provide a uniform rate of deceleration during the operation.

3. The section of the decelerator arm on which the bellcrank roller works. The distance of the roller from the pivot point of the decelerator arm affects the amount of angular rotation the decelerator arm receives. The same amount of motion from the roller rotates the arm farther and faster if it is applied closer to the pivot point of the arm. This is the adjustment point.

Tabulator Mechanism

The tab mechanism enables the operator of the machine to put typing in accurate, orderly columns by rapidly moving the carriage to preset positions. Study the tabulator mechanism illustrated in figure 15-57. Follow all the levers and links from the tab keylever around to the centrifugal governor.

When the operator depresses the tab keylever, a connecting link activates the tab cam, which starts the movement of all links and levers to release the escapement pawl from the escapement rack to allow rapid movement of the carriage. When the carriage reaches the desired position, the carriage is stopped, the tab is

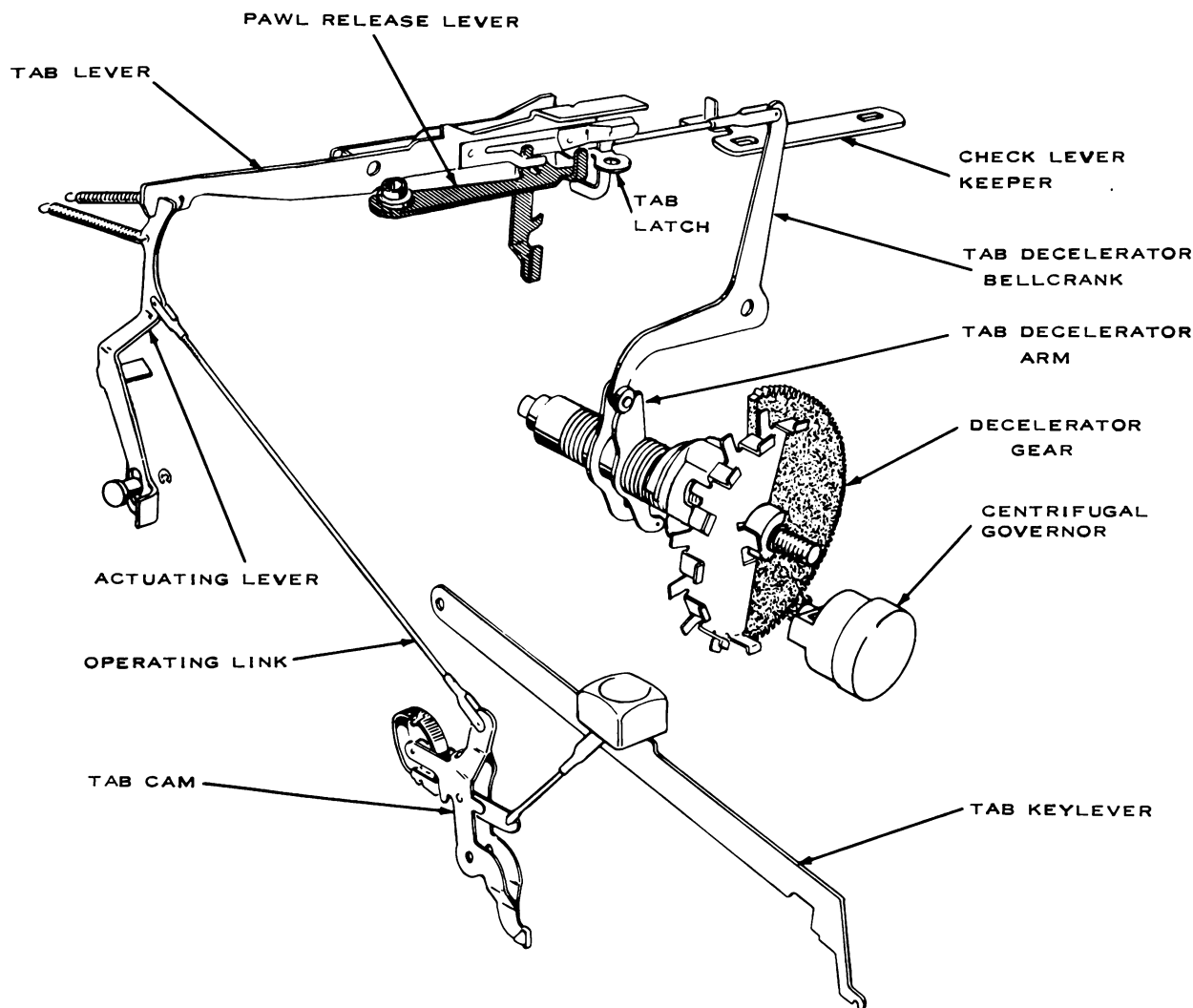


Figure 15-57.—Tabulator mechanism (electric typewriter).

91.45X

unlatched, and the escapement pawl is restored to the rack. The position of the tab set stop determines where the carriage stops, and in which tooth of the escapement rack the pawl re-enters and holds. Carriage speed is decelerated during its last 1/2 inch of travel to reduce the shock of stopping the carriage.

Tab stops are set by a tab set finger, shown in figure 15-58. Note also the tab clear arm.

The typist may set any stop from a rack of tab stops on the carriage (illustrated). Tab columns can be positioned with a minimum of two spaces between columns. When the TAB CLEAR lever is depressed, it clears the tab stops (all of them at one time if the tab clear button is held depressed during a full-length carriage return). Spring fingers in the rack hold the stops in either the SET or CLEARED position.

The basic part of the tab mechanism is the tab lever assembly, so mounted on a bracket that it can pivot forward and backward, and up and down. There are three parts to this as-

sembly. See figure 15-59. Note the pivot point, where it is fastened by a stud to the mounting bracket. Other parts of the assembly are mounted to this lever, as illustrated. The front side of the tab lever has a hook which pivots the pawl release lever and removes the pawl from the rack when the tab is operated. A projection of the tab lever extends down and toward the rear of the machine. The vertical portion of this projection provides contact surface for the tab latch; the lower portion operates a carriage return tab interlock which allows the tab to supersede carriage return. Two heavy studs riveted to the rear of the tab lever support the margin control and tab check levers. You already know the function of these levers.

Carriage Return Mechanism

The carriage return mechanism returns the carriage to the left margin and turns the platen ratchet to space the paper. If the carriage is already at the left margin, carriage return is a linespace operation only.

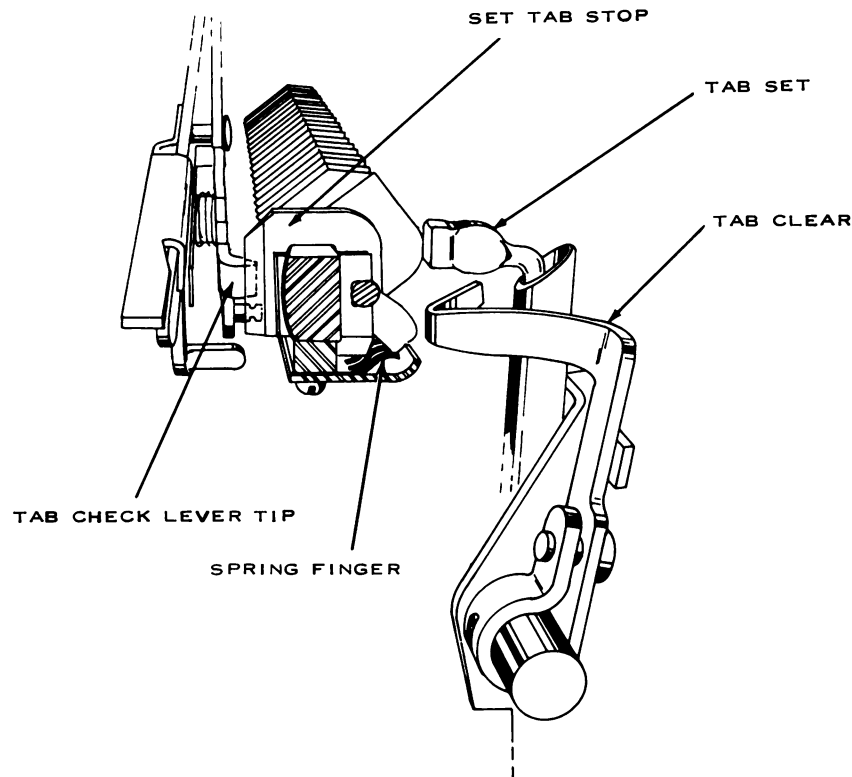


Figure 15-58.—Tab set and tab clear levers.

91.46X

Study the carriage return mechanism illustrated in figure 15-60. The carriage return tape is fastened to the left side of the carriage and passes under the carriage to the right side of the machine, over a pulley, and to the carriage return pulley, to which it is secured. When the pulley is rotated by the carriage return clutch, it winds the tape and pulls the carriage to the right.

A clutch disk (fig. 15-61) is mounted on the end of the power roll shaft, between the clutch pressure plate and the clutch pulley. Operation of the clutch compresses the clutch disk and pulley together, and causes them to rotate as a unit to wind the carriage return tape. The speed of the carriage on return is dependent upon the speed of the power roll and the diameter of the clutch pulley.

When the carriage return keylever button is depressed, it releases a single-lobed cam, which revolves and pulls the clutch lever toward the front of the machine. The clutch lever then pivots to move the clutch operating arm against the clutch plate which, in turn, presses the rotating clutch disk against the clutch pulley. This action causes the pulley and plate to rotate with the disk and wind the carriage return tape. The initial pull on the tape spaces the platen and causes the carriage to return to the right.

As the carriage return cam pulls the clutch lever forward, the clutch latch is moved by spring tension to its latched position. This movement also causes a pull on the clutch latch link and rotates the clutch latch bellcrank, thereby positioning the clutch unlatching link and carriage return/tab interlock (fig. 15-60). The latch holds the clutch compressed until the carriage reaches the LH margin.

The amount of clutch pull on the carriage is controlled by the clutch compression adjustment (fig. 15-61). As illustrated, the lower end of the clutch operating arm is mounted on a pivot shaft, one end of which is spring-loaded to the left by a compression spring. Tension of this spring can be adjusted by a locknut on the clutch arm retaining bolt. This tension regulates the amount of pressure applied against the friction disk. The clutch must be so adjusted that it will return the carriage from any position, but at the same time allow enough slippage of the disk to hold the carriage against the pull of the clutch without stalling the motor.

To release the escapement pawl from the rack, the clutch lever pulls a rear clutch lever link, which rotates the clutch lever bellcrank and pulls the pawl release link. This pivots the pawl release bellcrank about its mounting stud, which action then lifts the hook-shaped lug on the intermediate pawl release lever. Study figure 15-62. As this assembly moves, it rotates

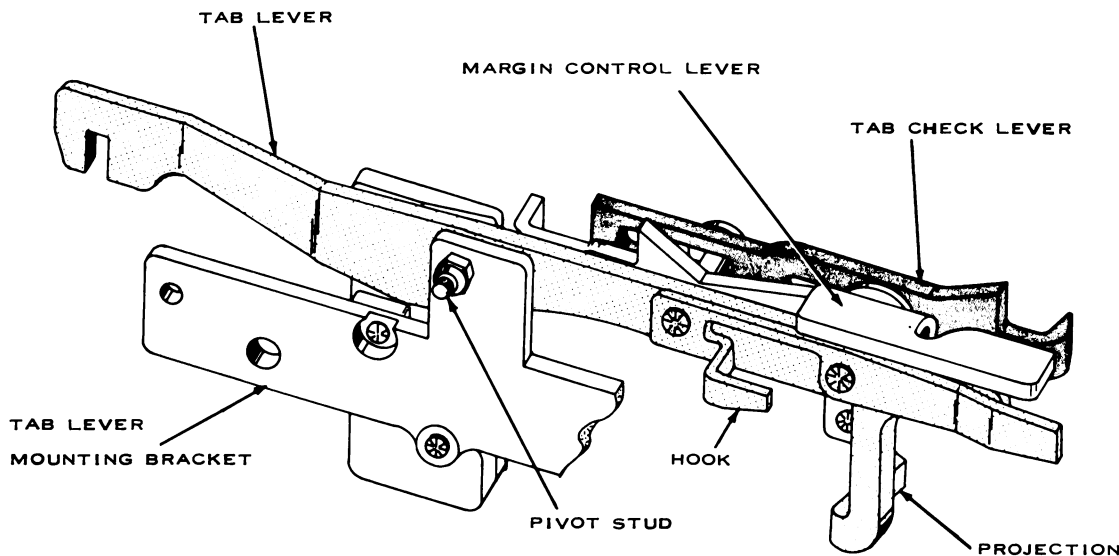


Figure 15-59.—Tabulator lever assembly.

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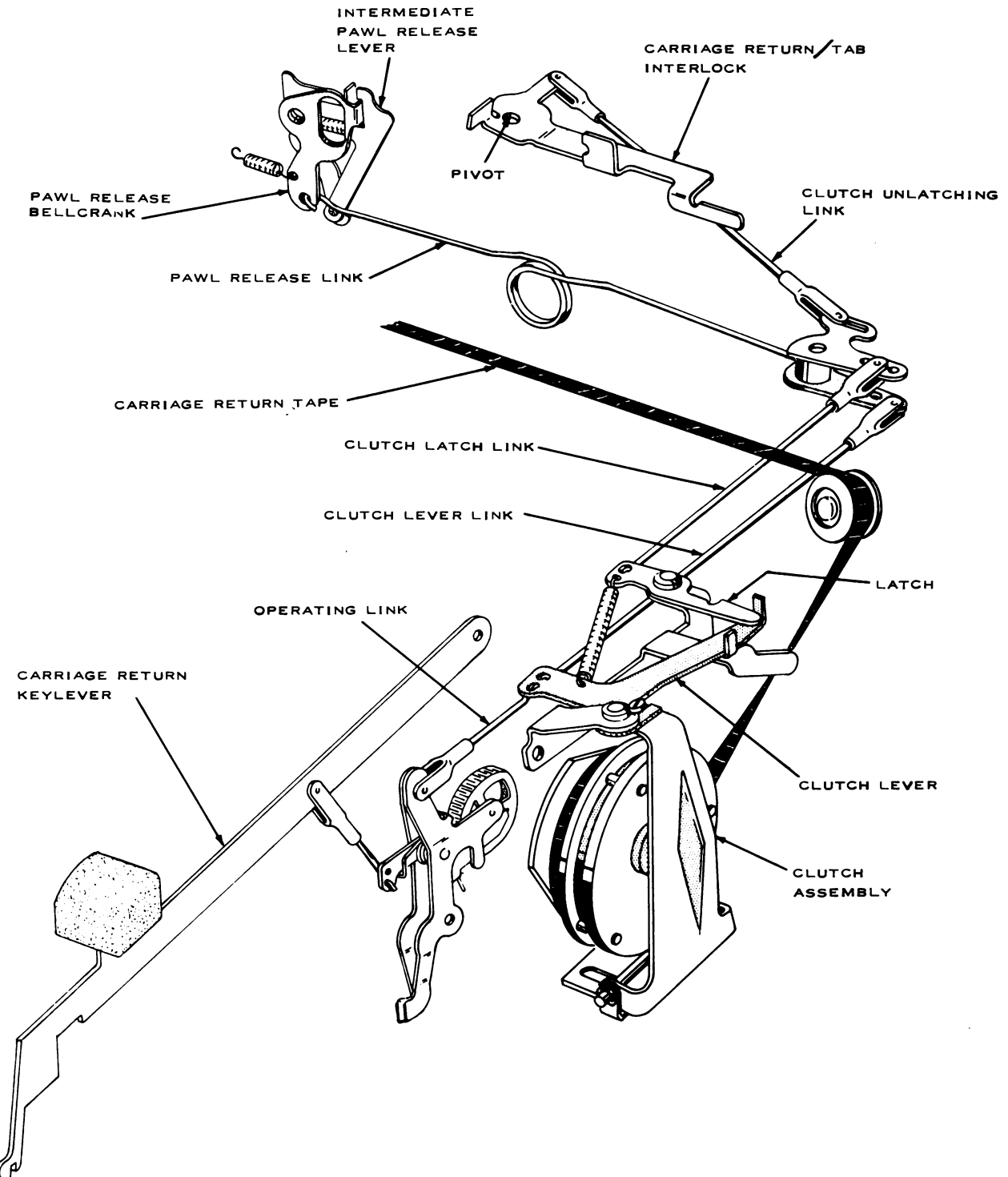
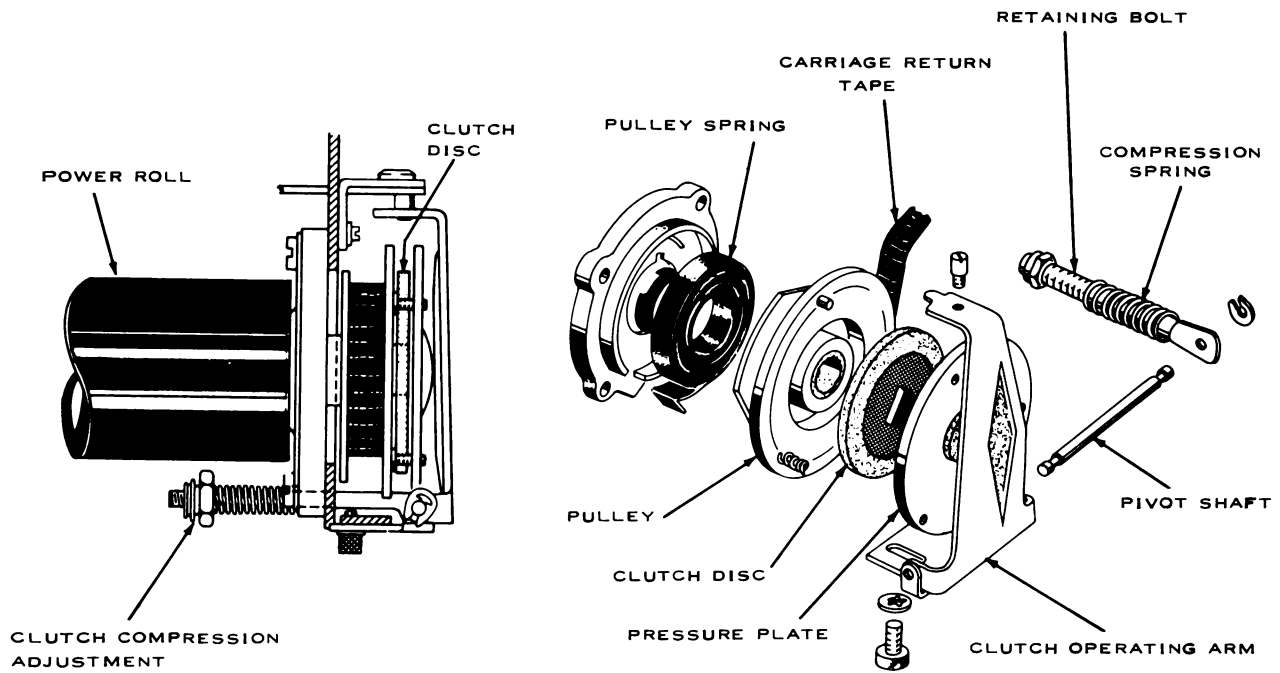


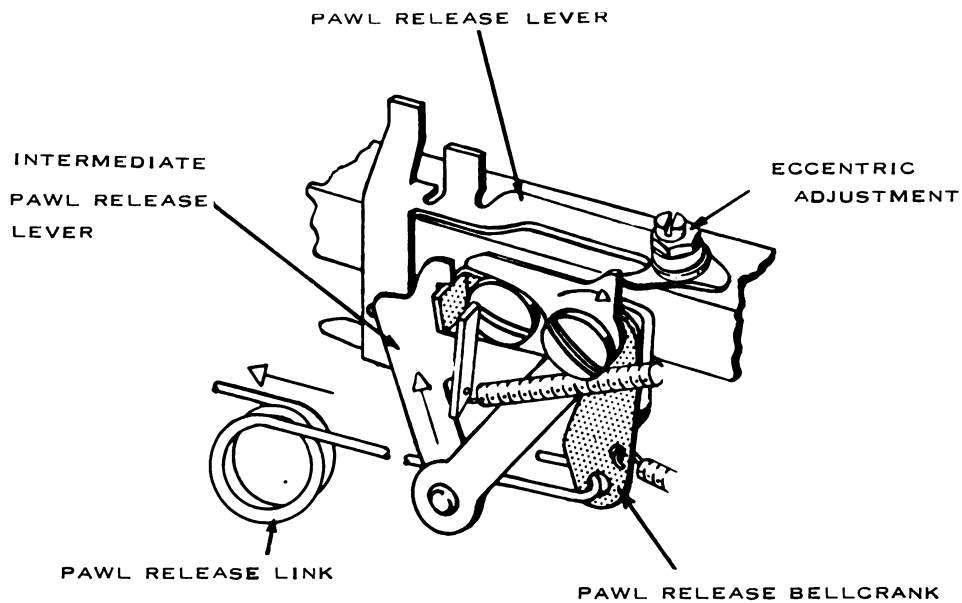
Figure 15-60.—Carriage return mechanism.

91.48X



91.49X

Figure 15-61.—Carriage return clutch.



91.50X

Figure 15-62.—Pawl release mechanism.

the pawl release lever and releases the escapement pawl from the escapement rack. The pawl release lever also operates the backspace interlock to prevent the backspace pawl from entering the escapement rack during carriage return.

As the carriage approaches the left margin, the left margin stop contacts a margin control lever, mounted through elongated holes to a stud on the tab lever (fig. 15-63). (The elongated holes allow sliding motion to the left and to the right.) The margin control lever is spring-loaded to the left. When the LH margin stop contacts the margin control lever it slides the margin control lever to the right. A lug on the margin control lever pivots the margin control bellcrank. This bellcrank has three functions:

1. It operates the carriage return decelerator bellcrank to decelerate the carriage (fig. 15-63).

2. It pushes the intermediate pawl release lever to disengage it from the pawl release bellcrank. This action allows the pawl release lever to restore to its rest position and the escapement pawl to return to the escapement rack.

3. It rotates the carriage return/tab interlock to unlatch the clutch.

CARRIAGE OVERBANK.—After the carriage reaches the limit of its travel to the right, and all clutch parts are restored to the rest position, the carriage settles back a small distance to the left under mainspring tension. This motion is called **OVERBANK**. The amount of overbank is the amount of sliding motion in the escapement pawl (.058" or .038") plus the distance that the escapement rack tooth was required to travel beyond the pawl to ensure its dropping safely in front of the tooth (.010"-.015"), as shown in figure 15-64. The amount of this travel is controlled by adjusting the

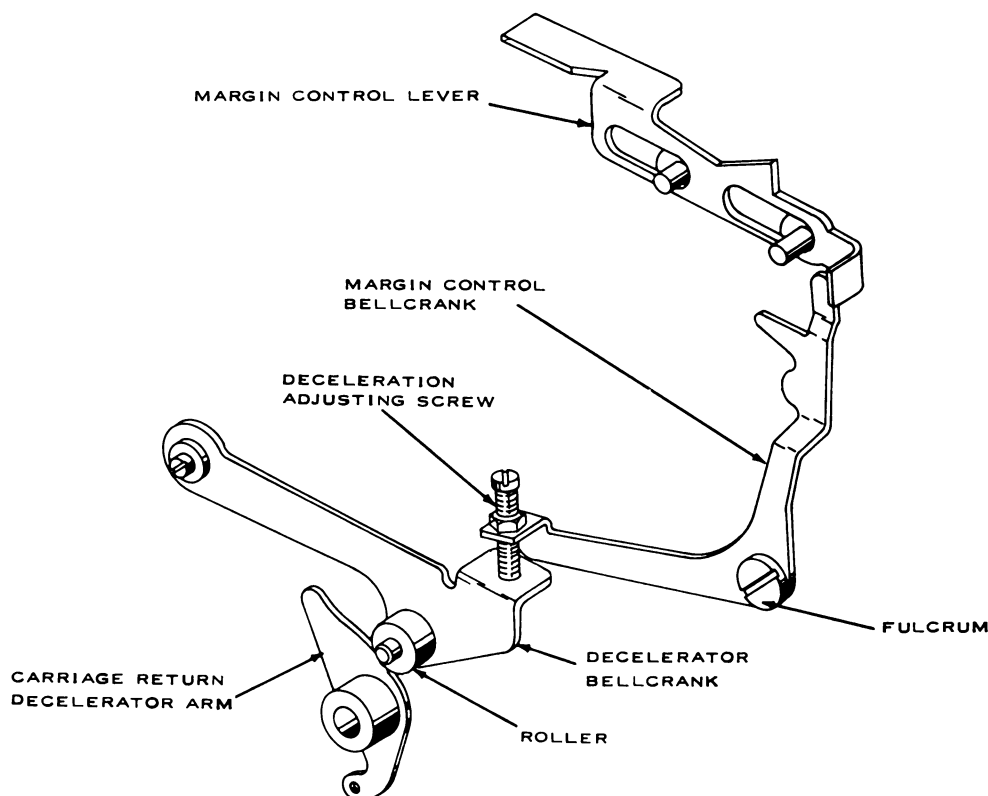


Figure 15-63.—Decelerator operation by margin control bellcrank.

91.51X

relative position of the margin rack to the escapement rack.

INTERLOCK OPERATION.—During carriage return, the carriage return tab interlock unlatches the clutch, as explained previously; interlocks the action between the carriage and return tab, as shown in figure 15-65; and interlocks carriage return and backspace. If the carriage return and tab are operated together, the tab lever actuates the interlock to unlatch the clutch or to prevent the clutch from latching (fig. 15-65). Tab operation supersedes carriage return. An operator can use this interlock feature to obtain a partial carriage return and tabulation to the nearest set tab stop by touching the tab key just after the carriage return key.

The third function of the carriage return/tab interlock is illustrated in figure 15-66. A flat extension of the right end of the carriage return/tab interlock follows the backspace interlock during carriage return. The backspace interlock must pivot around the backspace pawl and get out of the way of the carriage return/tab interlock to allow the amount of motion necessary for the latch to latch up the carriage return clutch. (Pawl release lever actuates the backspace interlock.)

When the backspace pawl is in the rack, it blocks rotation of the backspace interlock and therefore blocks rotation of the carriage return/tab interlock. This prevents the clutch from latching when carriage return is operated during a backspace operation. Clutch surfaces are brought together momentarily as the carriage return pawl rotates through its cycle and the pull on the tape spaces the platen. Carriage return is prevented because the clutch cannot latch up. This action results in a backspace and a line space. On a simultaneous backspace and carriage return operation, the backspace pawl moves into the escapement rack before the carriage return cam acts to rotate the pawl release lever. Hence, rotation of the backspace interlock and the pawl release lever is blocked.

Linespace Mechanism

Initial pull on the carriage return tape operates the linespace mechanism and indexes the platen (fig. 15-67). The tape pulls the index pawl carrier down against the tension of the spring-loaded index lever. This allows the index pawl to engage a platen ratchet tooth and rotate the platen. When the index pawl carrier is in its upper rest position, the pawl is held clear of the

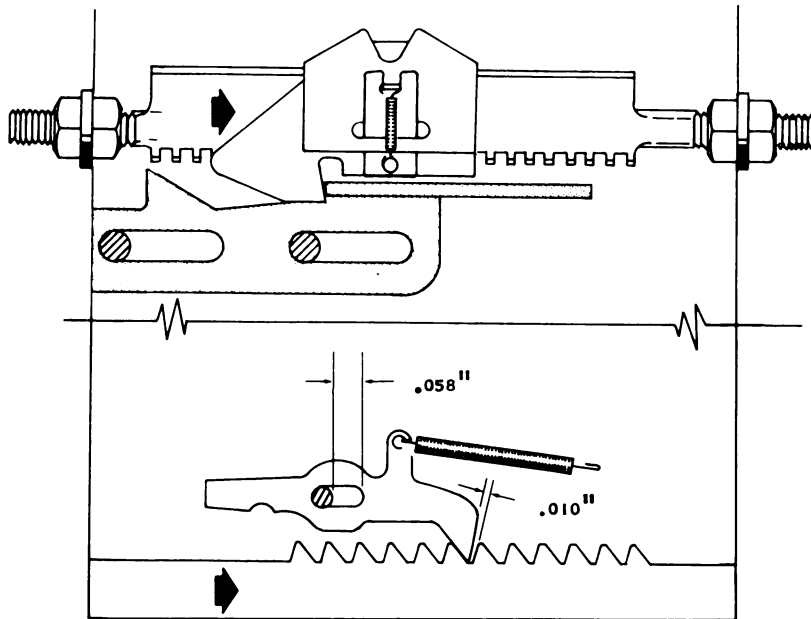


Figure 15-64.—Carriage overbank mechanism.

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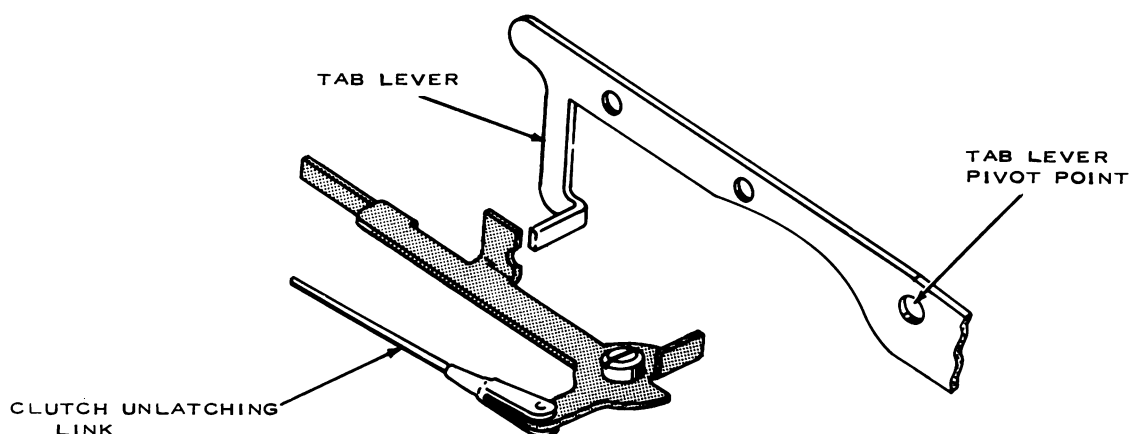


Figure 15-65.—Carriage return/tab interlock.

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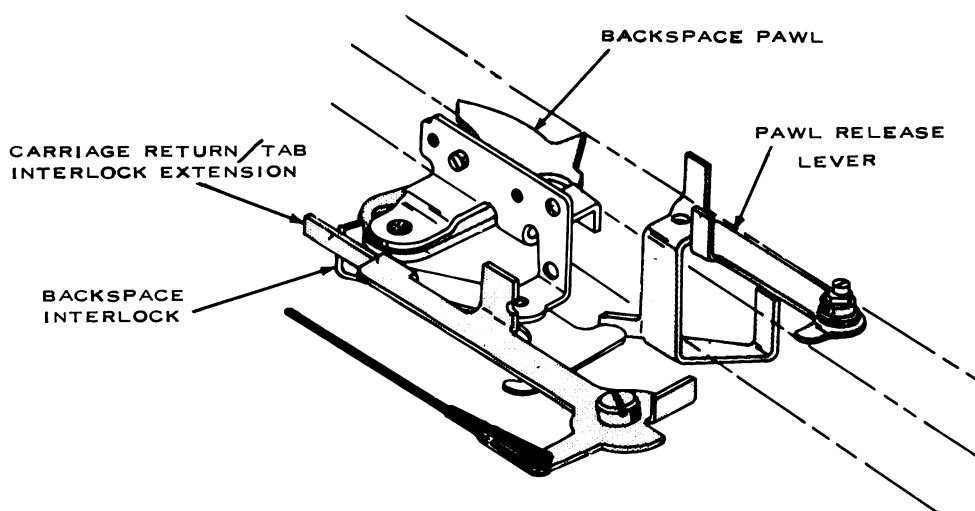


Figure 15-66.—Interlock, carriage return and backspace.

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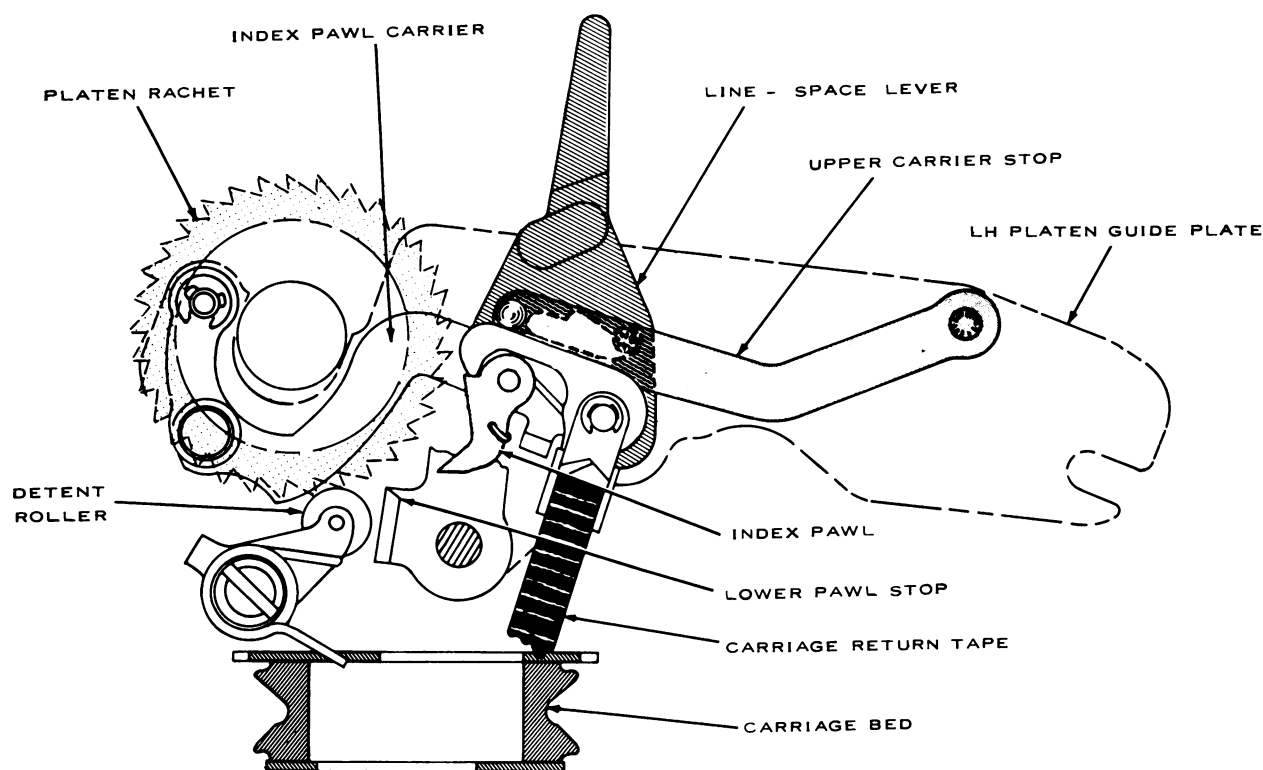
ratchet. As the carrier is pulled down, spring tension on the index pawl engages the pawl to the ratchet. Rotation of the ratchet causes a spring-loaded detent roller to ride over the point of a ratchet tooth. The rotation is stopped by an adjustable lower index pawl stop when the detent roller bottoms again between two ratchet teeth to hold the platen in the new position.

The detent release mechanism is shown in figure 15-68. When the line position reset lever

is pulled forward, it activates a cam which removes the detent roller from the ratchet and permits free rotation of the ratchet and platen.

Shift Actuating Mechanism

The shift mechanism raises and lowers the type basket to provide upper and lower case typing. The basket consists of the segment support, segment, type, and type rest. The assembly is suspended by four segment guides



91.55X

Figure 15-67.—Linespace mechanism.

(flat springs), and two toggle springs in the shift actuating mechanism hold the basket to the limit of its upper or lower position.

Up and down movement of the basket is limited by stop brackets mounted on the power frame. The distance the basket moves in going from one case to the other is called **SHIFT MOTION**. This distance corresponds to the distance on the type slug from the foot of the upper-case character to the foot of the lower-case character. Most IBM electric typewriters have a motion of .265 inch, but a few of the larger types have a motion of .300 inch. Shift motion is adjusted by the nuts on the stop screw, which regulates the distance between the upper and lower bumper washers. This adjustment is correct when upper and lower-case characters print on the same writing line.

Study the shift actuating mechanism shown in figure 15-69. Toggle links at the left and right sides of the basket assembly connect the segment support to a toggle and shaft assembly. The toggle levers are fastened to each end of

the shaft, which is mounted in bearings in the power frame. Rotation of the shaft and toggle levers moves the toggle links up or down to shift the basket. Two heavy toggle springs (mounted between studs on the side frames and studs on the toggle levers) hold the basket assembly in either the fully raised or lowered position. These springs also help to move the basket during shifting.

RH TOGGLE LEVER.—The RH toggle lever has a shift plate assembled to it, as shown in figure 15-70. The upper and lower pins illustrated receive the action from the shift cam. Holes for the pins are elongated to allow for adjustments, to provide equal pusher-to-pin clearance on upper and lower pins.

Toggle levers on both sides of the machine are secured to the shaft in matched positions so as to obtain equal toggle action on each side. They are not adjustable. Cam action on the upper pin of the shift plate rotates the toggle levers and the shaft assembly to pull the basket DOWN.

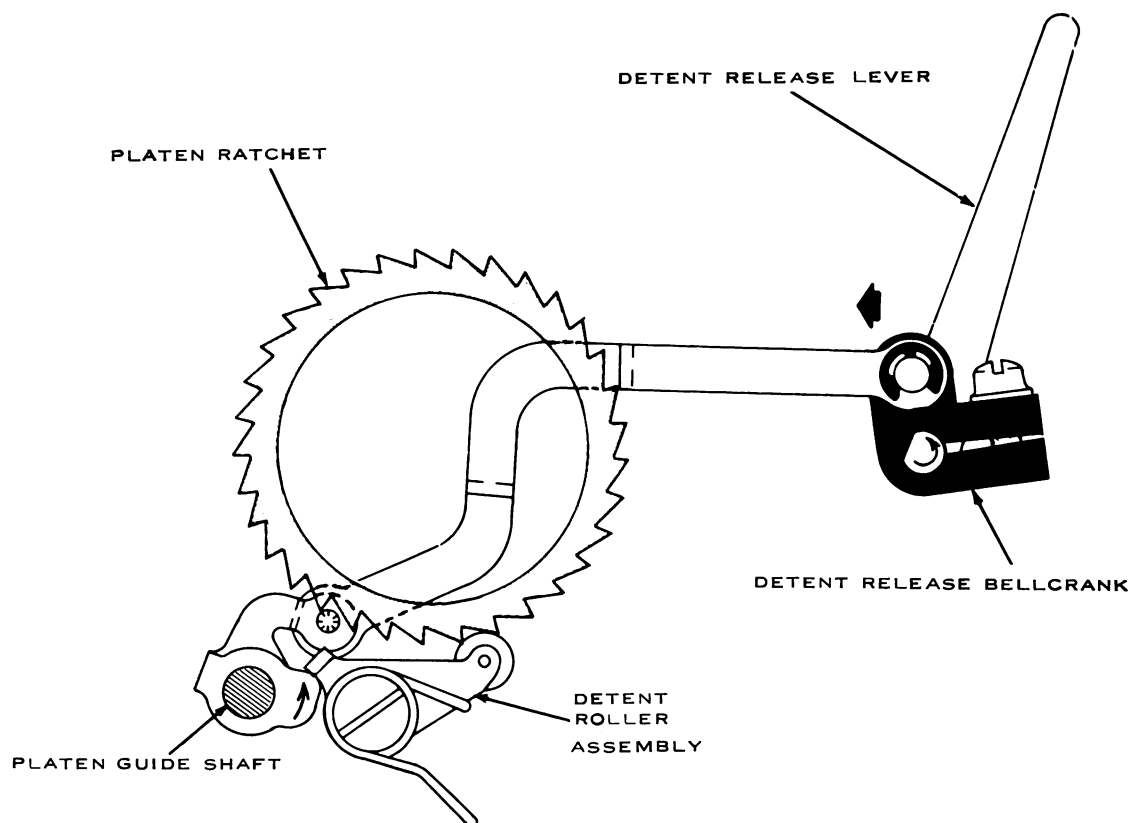


Figure 15-68.—Detent release mechanism.

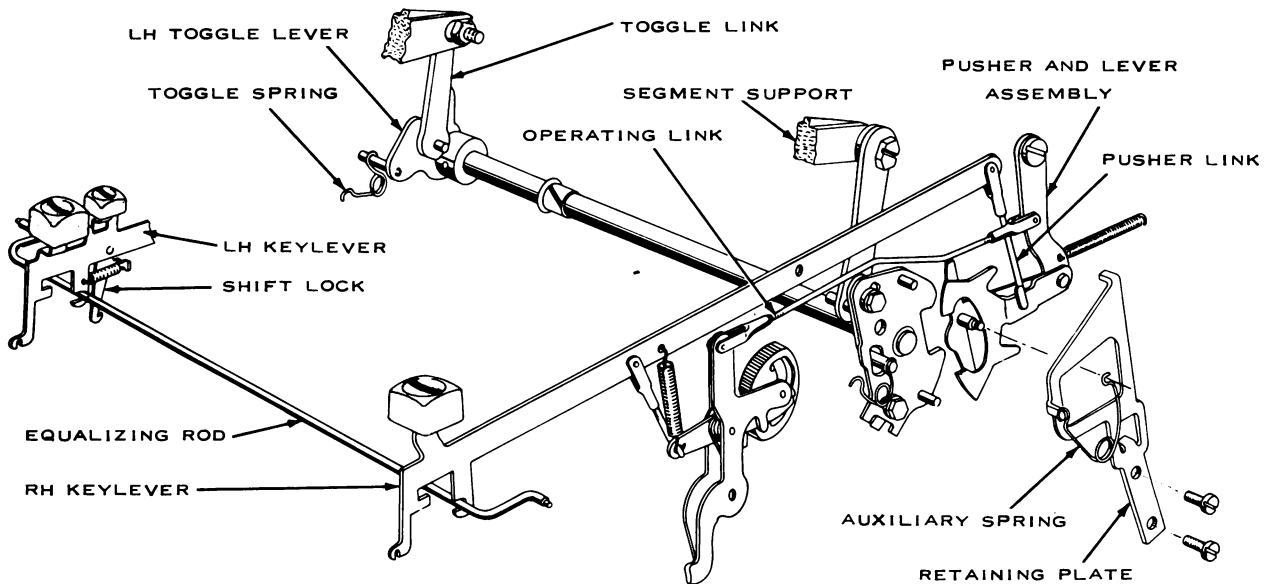
91.56X

Cam action on the lower pin pushes the basket UP. The shift cam is a double-lobed, double-acting type. Double acting means that the cam is released to rotate over one lobe when the key button is depressed, and released again to rotate over the second lobe when the key button is released.

SHIFT PUSHER AND LEVER ASSEMBLY.—The shift pusher and buffer (fig. 15-71) are riveted to the shift actuating lever. An adjustable link connects the right shift keylever to the pusher lever. When the front end of the keylever pivots down to release the shift cam, the rear end of the keylever pivots up and positions the pusher behind the upper pin at the time of release of the cam.

The buffer (lever) moves forward and backward with the pusher lever (fig. 15-71). The buffer is a shock absorber which prevents the basket from slamming noisily into position. It engages the lower pin of the shift plate after the pusher rotates the plate by means of the upper pin. The buffer limits the rotating speed of the shift plate to the speed of the buffer as it moves to the rear. The shift cam (symmetrically oval) remains engaged with the power roll even after it passes over the high point. The shift pusher and buffer therefore restore to the rest position ONLY as fast as the rotation of the cam and power roll permits.

When one shift key button is depressed, the other shift key button is also depressed through the equalizing rod. As the rear of the shift



91.57X

Figure 15-69.—Shift actuating mechanism.

keylever rises, it lifts the pusher link and the shift pusher lever. The pusher lever rises until its upper arm is directly behind the upper pin of the shift plate (part A, fig. 15-72). The same key-lever operation also lowers the cam release link to release the cam to the power roll. As the cam rotates to its high point, it pulls the operating link forward. The operating link pivots the actuating lever about its mounting screw to bring the pusher and buffer forward. This action causes the shift plate and toggle levers to rotate counterclockwise against the tension of the toggle spring.

Rotation of the shift plate and RH toggle lever assembly by the pusher causes rotation of the actuating shaft and the LH toggle lever assembly. When the cam reaches its high point, the pusher action ceases (part B, fig. 15-72). During the preceding action, the buffer moved forward with the pusher but did no work. As the right and left toggle links pull down on the basket, the momentum of the basket continues the rotation of the toggle and plate assembly and the upper pin leaves the pusher. This rotation carries the toggle springs over center and their spring tension then powers the operation to its completion.

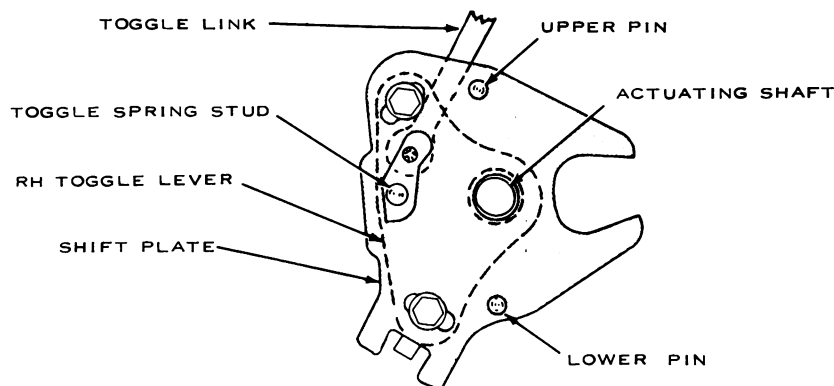
As the shift plate assembly continues to rotate, the lower pin contacts the lower arm of the buffer (part C, Fig. 15-72). Restoration of the

buffer to the rear is controlled by the receding surface of the cam still engaged with the power roll. Cam action slows down the restoring action of the toggle springs to prevent slamming of the segment support against the stop brackets.

Backspace Mechanism

The backspace mechanism of an electric typewriter is shown in figure 15-73. When the backspace keylever is depressed, a link between it and the backspace cam overcomes the tension of the cam release lever spring and releases the single-lobed cam to the power roll. As the cam rotates on the power roll, an operating link connected to the top of its frame causes the backspace bellcrank to rotate and pull the rear link attached to the backspace pawl.

Mounted through an elongated hole, when pulled to the right, the backspace pawl is cammed into the escapement rack (part A, fig. 15-74). Two springs connected to the head of the backspace pawl delay the movement of the head to the right until the backspace pawl is engaged in the escapement rack (part B, fig. 15-74). A guide lug (shown) directs the pawl tip to bottom safely on a rack tooth. When the pawl engages a tooth of the rack, pull on the linkage pivots the pawl on its mounting stud and moves the carriage to the right (part C, fig. 15-74). This motion



91.58X

Figure 15-70.—RH toggle lever and shift plate assembly.

continues until the carriage moves far enough to allow the escapement pawl to snap into the next tooth of the escapement rack (part D, Fig. 15-74). At this point, the backspace pawl stop halts the backspace pawl, which then prevents further motion of the carriage to the right.

A backspace interlock mounted on the backspace pawl bracket performs two functions:

1. It prevents backspace operation any time the escapement pawl release lever is operated.
2. It prevents pawl release any time the backspace is operated.

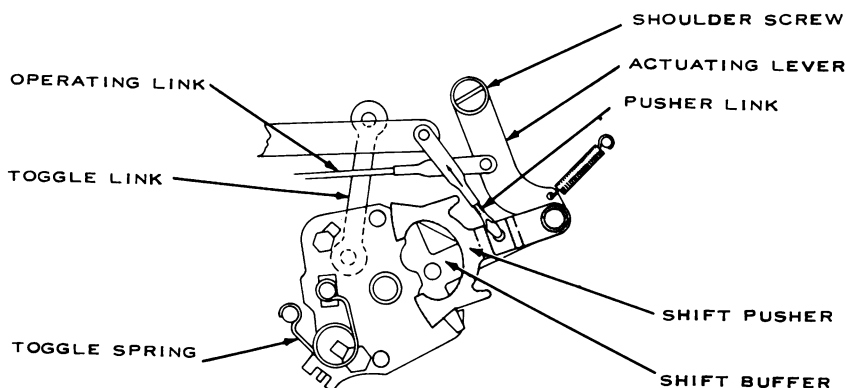
Study the backspace interlock shown in figure 15-75. It is actuated by the pawl release lever during tabulation, carriage return, or manual carriage release. This interlock does not prevent the backspace pawl from rotating, but it

does prevent the pawl from engaging the escapement rack, by holding the pawl at its mounting stud to keep it from sliding into the rack. The backspace cam operates the linkage; the pawl merely pivots on the lug of the interlock and passes clear of the escapement rack and pawl stop.

If the backspace pawl has already entered the escapement rack for a backspace operation, the interlock is blocked and cannot rotate. In this manner, the interlock blocks the pawl release lever and prevents it from pulling the escapement pawl out of the rack, which prevents movement of the carriage.

Ribbon Mechanisms

The different ribbon mechanisms discussed in this section are: ribbon lift, ribbon feed,



91.59X

Figure 15-71.—Shift pusher and lever assembly.

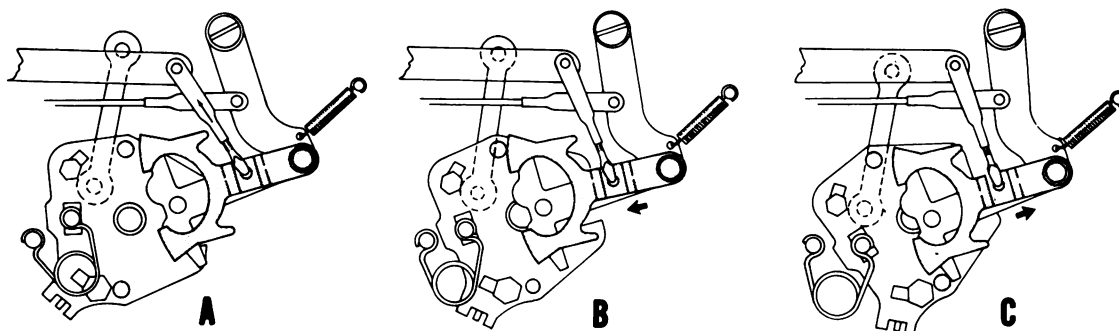


Figure 15-72.—Shift actuating sequence.

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ribbon reverse, and ribbon rewind. The ribbon lift and ribbon feed mechanisms are the two major ones. Each mechanism is discussed in as much detail as space permits.

RIBBON LIFT MECHANISM.—Because it is important to have the line being typed visible, a typewriter ribbon rests below the line of type. The ribbon must therefore be raised before the typeface each time a type bar is raised for printing. Letter cams provide the motion necessary to raise the ribbon when the typeface approaches the platen. A restoring spring returns the ribbon lift mechanism to its rest position after a typeface prints.

A ribbon position lever on the keyboard has four positions for controlling the height of ribbon lift, three lift positions and a stencil position (ribbon not raised). The three ribbon lift positions enable a typist to utilize the top, middle, and bottom portions of the ribbon.

When a letter cam is operated, it rotates a bail about its mounting studs on the left and right side frames. See figure 15-76. The bail has a ribbon cam release link at its left end, and a ribbon-lift link at the middle. Rotation of the ribbon-lift bail pushes the ribbon-lift link to the rear, causing an actuating lever to pivot and pull forward on the center of a toggle assembly. This action increases the angle between the toggle arms sufficiently to raise the ribbon lift lever from its rest position. The ribbon lift lever then raises the center guide and positions the ribbon in front of the typeface.

The amount of ribbon lift at any time depends upon the angle of the two toggle arms. An operator changes this angle every time he changes the position of the ribbon position lever. Study the illustration to learn how this is accomplished.

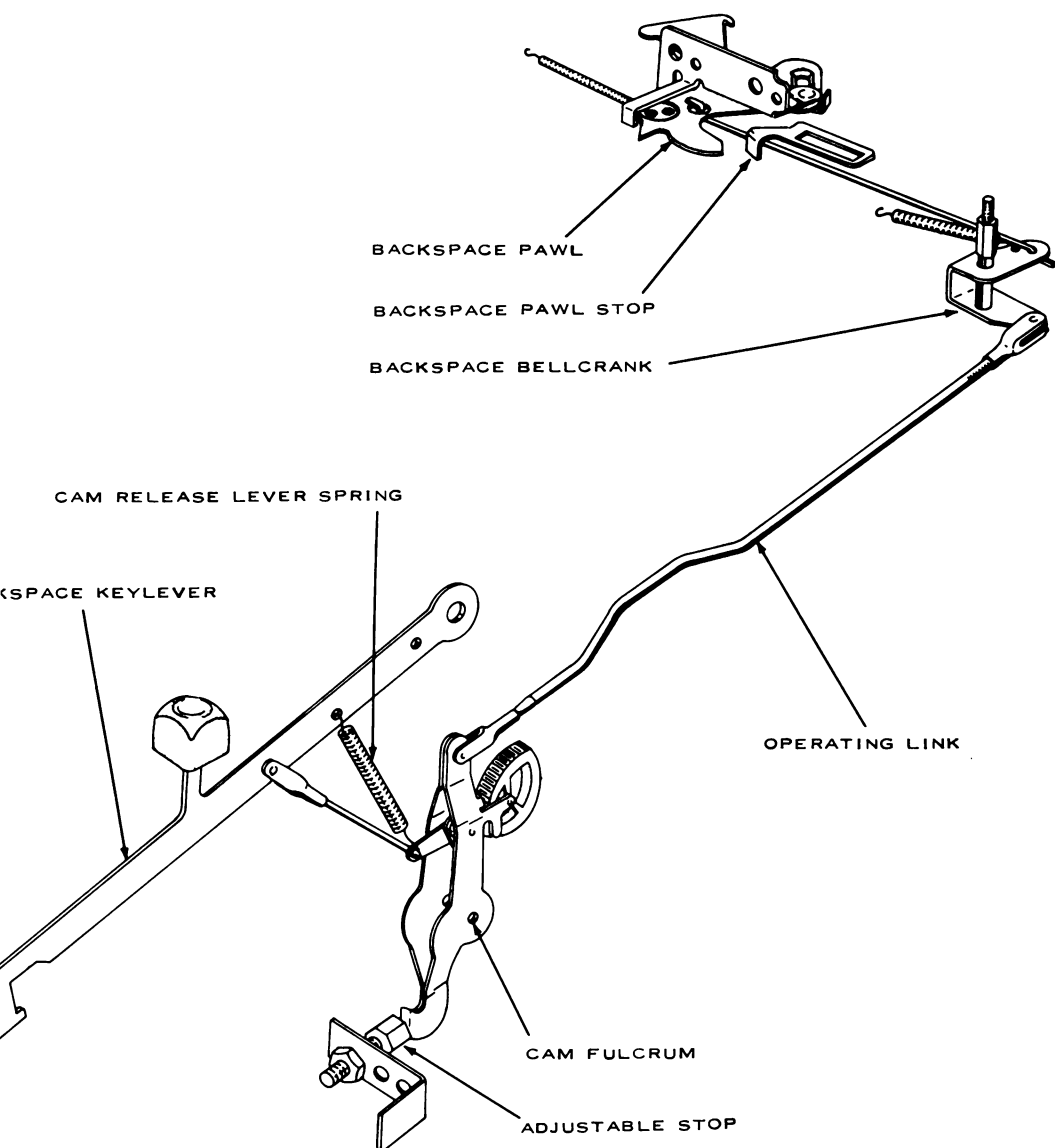
A link from the position lever rotates a shaft and its attached positioning plate, which controls the angle of the toggle assembly by positioning the lower toggle arm attached to it. A spring-loaded detent roller holds the plate in one of four positions.

RIBBON FEED MECHANISM.—Every time there is a type bar operation, the ribbon feed mechanism operates. By means of bellcranks and spring clutches, the ribbon feed cam rotates a geared drive shaft. Study figure 15-77. The drive shaft is moved laterally to enlarge right or left spool mechanisms. When the drive shaft is to the left, the ribbon winds onto the LH spool, and vice versa. The shaft is spring-loaded to the left and the spring holds it in the LH feed position. The shaft is cammed to the right and held in the RH feed position by a latch. Ribbon feed direction reverses automatically when either spool becomes empty.

Operation of any letter cam actuates the ribbon feed mechanism. Rotation of the ribbon lift bail is transferred to the ribbon cam release lever by the cam release link, which is attached to the LH side of the bail. Actuation of the cam release lever allows the ribbon cam to engage the power roll.

When the ribbon cam rotates, it raises the cam frame (fig. 15-77); and an operating link from the cam frame to the ribbon feed bellcrank rotates the bellcrank. A feed link connects the outer arm of the bellcrank to an upper arm on the drive shaft, and motion from the cam and ribbon feed bellcrank causes the upper arm to move up and down.

A spring clutch connects the upper arm to a drive wheel fastened to the drive shaft. When the arm is raised, the spring clutch tightens and



91.61X

Figure 15-73.—Backspace mechanism (electric typewriter).

ive wheel; when the arm is lowered, clutch relaxes and slips about the drive a second spring clutch and non-rotatable assembly tighten when the upper arm and prevents backward rotation of wheel. Reciprocating motion of the ribbon is therefore transformed into rotation of the drive wheel and shaft.

ive gears transfer drive shaft rotation to ribbon spools through left or right. A reverse lever mounted at the left

side of the keylever bearing support is keyed to a drive shaft collar fastened to the drive shaft by setscrews. As the drive shaft moves laterally, the reverse lever pivots about its mounting stud on the keylever bearing support. A spring fastened to a lower arm of the reverse lever puts spring tension on the drive shaft to the left.

RIBBON REVERSE MECHANISM.—The ribbon reverse mechanism of the C-1 machine is illustrated in figure 15-78.

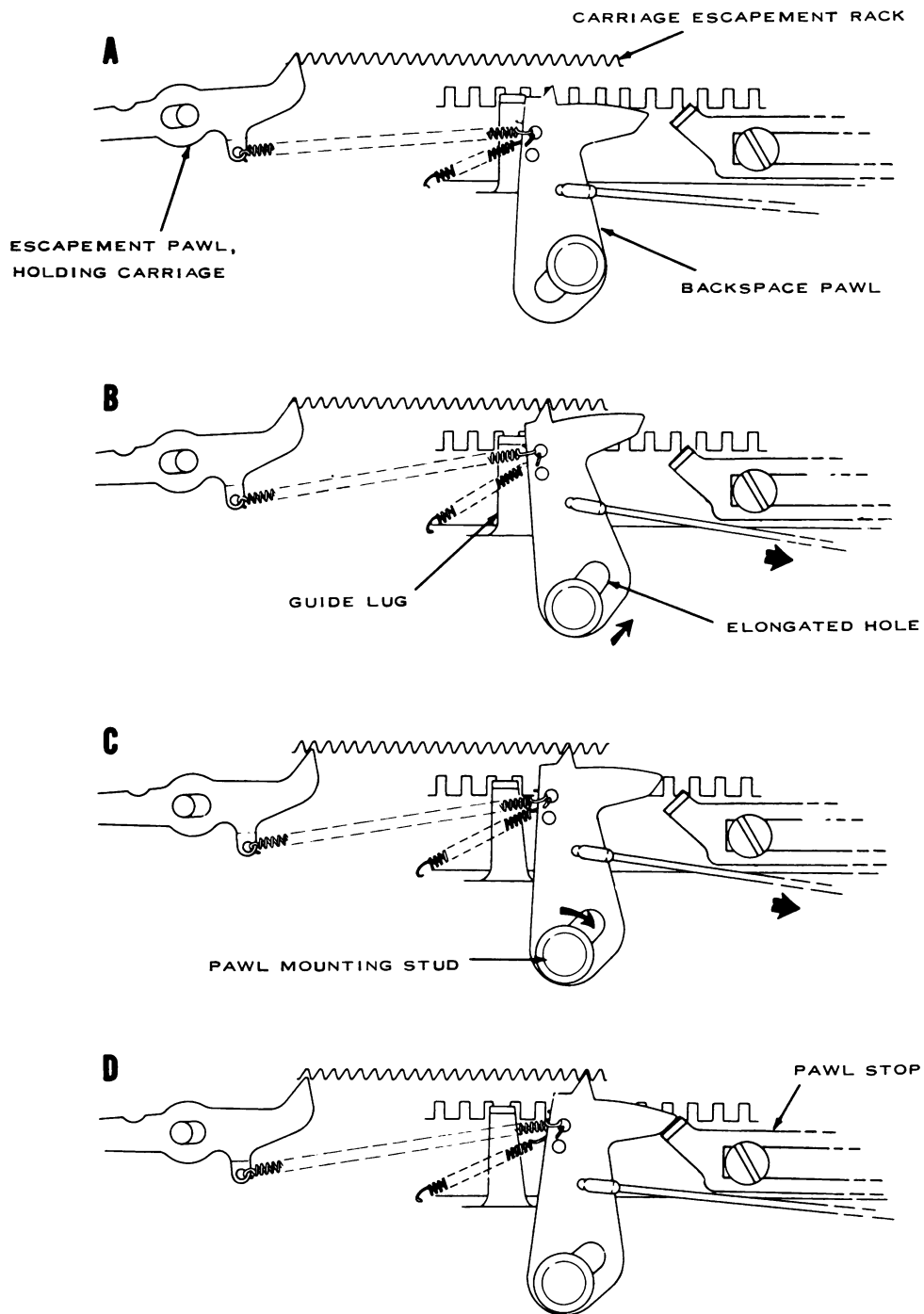
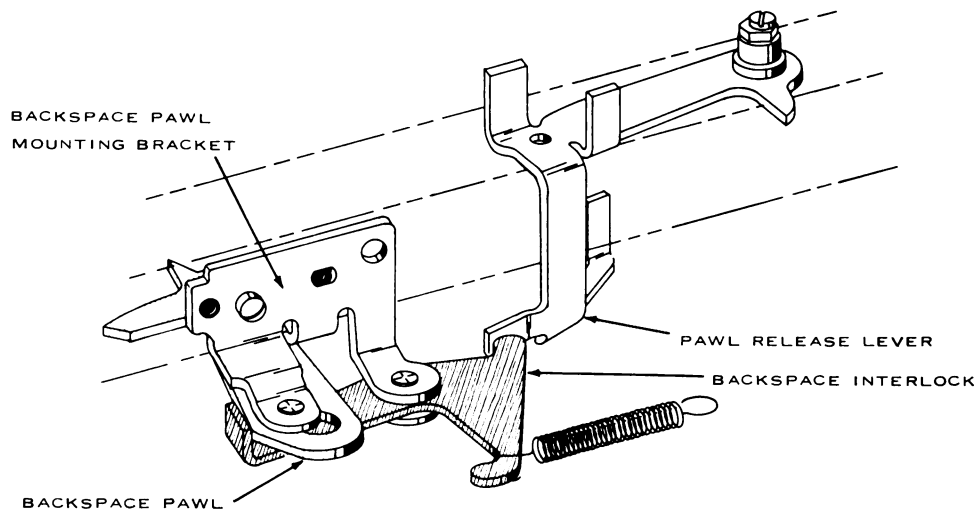


Figure 15-74.—Backspace pawl sequence.

91.62X



91.63X

Figure 15-75.—Backspace interlock (rear view).

A sensing finger of the ribbon reverse mechanism bears against the ribbon of each spool and initiates reverse operation when the spool becomes empty. Feed is reversed when the drive shaft shifts laterally and winds the ribbon onto the empty spool. The drive shaft is moved to the right against the tension of the reverse lever spring by a reversing cam. The right sensing finger operates the reversing cam when the RH spool is empty.

The LH sensing finger is held by a spring which pulls it in a counterclockwise direction. The finger pivots about a shaft on the sensing cam. An eccentric washer mounted on the cam acts on the unlatching lever, which pivots about the same shaft as the sensing finger cam, but it is not connected to the cam.

As the LH spool empties, the LH sensing finger falls into an opening in the hub of the ribbon spool. This movement of the sensing finger rotates the sensing finger cam by acting on a rear upright lug of the cam. Rotation of the sensing finger cam causes the eccentric washer to pivot the unlatching lever to the rear. A link from the unlatching lever pulls the reverse lever latch from the reverse lever, allowing the reverse lever spring to pivot the reverse lever clockwise and pull the shaft to the left.

A two piece primary-secondary cam assembly is attached to the right end of the drive shaft (fig. 15-79). The secondary cam is secured to the

drive shaft by a setscrew; the primary cam rotates with it but is not secured to the drive shaft. The two sections of the cam are secured together (spring-loaded) to have them rotate as a unit during normal ribbon feeding. These sections can also rotate independently when forced away from each other. If the primary cam is prevented from rotating, the secondary cam is forced to the right, providing lateral movement of the drive shaft required to engage the RH ribbon spool feed.

The RH sensing finger is welded to a shaft which pivots on the right end of the keylever bearing support, and the RH sensing cam is attached to this shaft by a setscrew. The sensing finger is spring-loaded toward the RH ribbon spool hub by the sensing cam spring, and a reversing pawl is mounted to the right end of the keylever bearing support. An upright stud on the tail of the pawl rides in a camming slot of the sensing cam.

The RH ribbon spool has an opening in the hub that is covered by a plastic gate which prevents the spring-loaded sensing finger from pressing into the spool slot before the RH spool is empty. As the RH spool empties, the plastic gate swings open and the RH sensing finger enters the opening in the spool hub, rotating the RH sensing cam. The cam slot rotates the reversing pawl, and the reversing pawl engages a tooth on the primary cam and stops

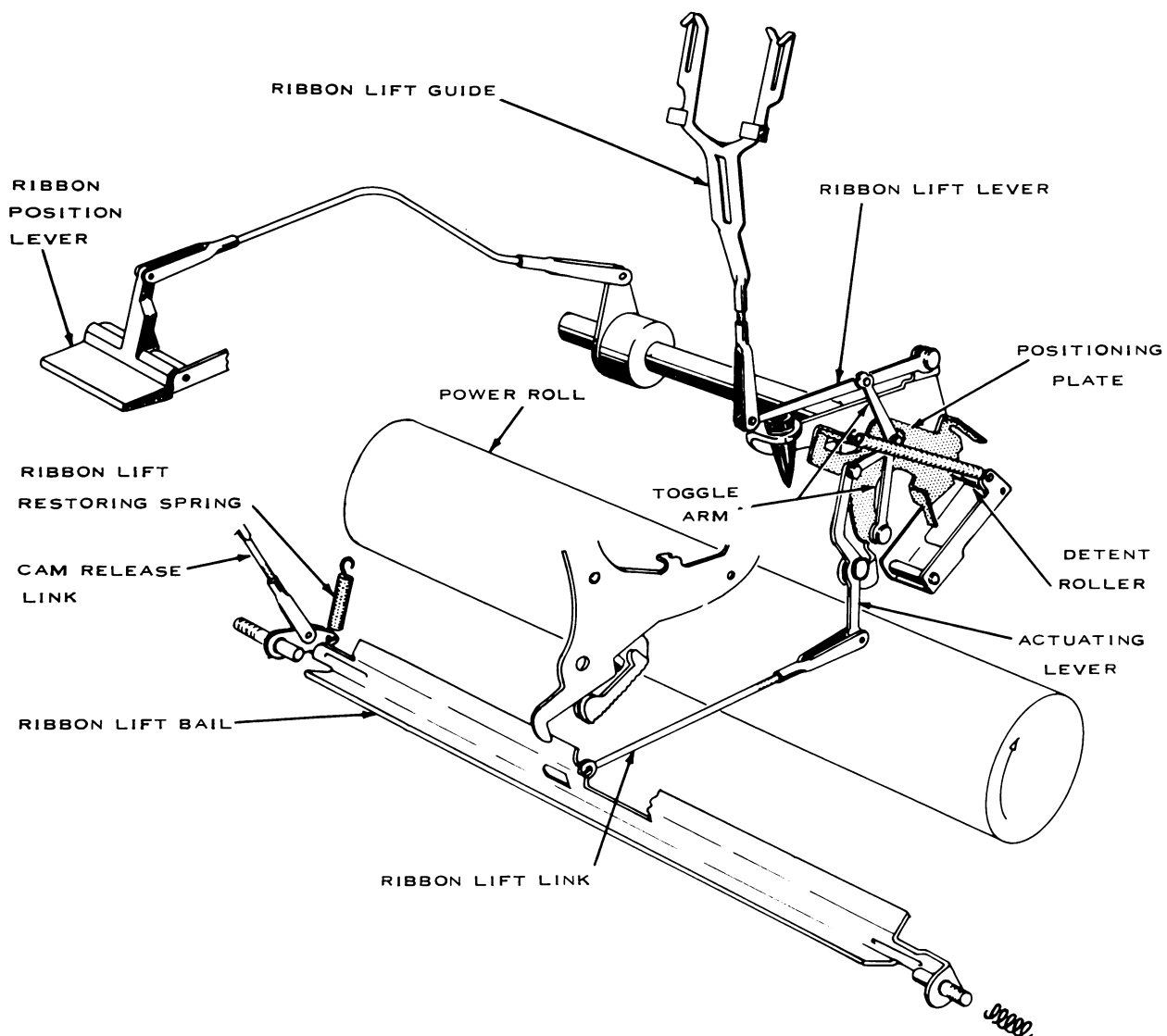


Figure 15-76.—Ribbon lift mechanism.

91.64X

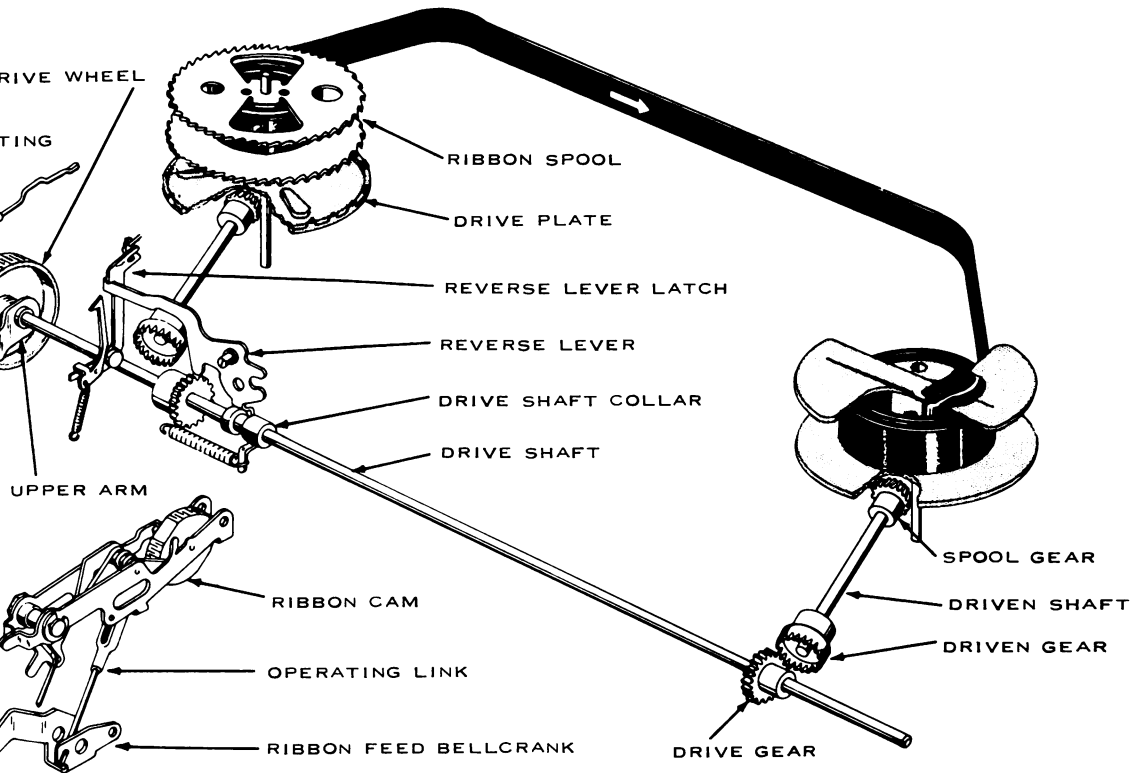
its rotation. As the secondary cam continues to rotate with the drive shaft, it climbs the camming surface of the primary cam, pulling the drive shaft to the right until the reverse lever latches.

RIBBON REWIND MECHANISM.—The rapid ribbon rewind feature winds a used ribbon onto the LH spool for changing in approximately 50 seconds. Motion from the power roll pulley rotates the ribbon drive wheel and drive shaft, shown in figure 15-80. Ribbon reverse is inter-

locked with the rewind mechanism to ensure that the ribbon will be wound onto the LH spool. When the RH spool becomes empty, the RH ribbon reverse action stops the rewind operation.

When the operator depresses the rewind button on the keyboard, the motion is transferred through the button link and button latch to raise the rewind lever. Study figure 15-81.

The rewind lever and the transfer wheel bellcrank are linked by a heavy spring (illustrated). As the rewind lever is raised, the



91.65X

Figure 15-77.—Ribbon feed mechanism.

ivots against the transfer wheel with
oll pulley and the drive wheel. When
utton is fully depressed and the re-
fully raised, the rewind latch springs
g on the rewind lever and holds the
chanism in the operating position
. The ribbon then rewinds to the left
l spool is empty.

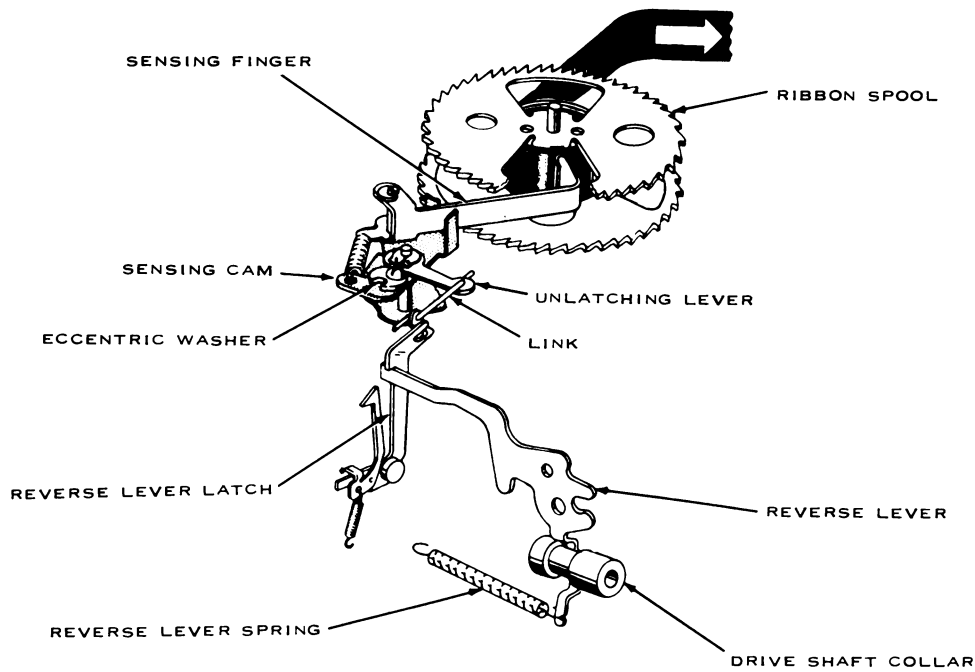
ribbon is feeding to the right when the
uates the rewind mechanism, ribbon
automatically reverse in order that
ribbon may rewind onto the removable
With the ribbon feeding to the right,
e lever is latched and a rewind lever
positioned over the rewind lever, as
figure 15-83. When the rewind lever
it engages the rewind lever latch,
s the reverse lever latch to the rear.
reverse lever is released, the drive
ee to spring to the left and operate
l for ribbon rewinding.

ribbon is already feeding to the left
rewind lever is raised, no reverse

action is necessary. When the reverse lever is
unlatched, the rewind lever latch is held to the
rear, clear of the rewind lever. When the RH
spool empties, ribbon reverse occurs. This
action moves the drive shaft to the right and
rotates the reverse lever counterclockwise. As
the reverse lever latches, a stud on the re-
verse lever strikes the tail of the rewind latch
to unlatch the rewind lever. When the rewind
lever drops, the transfer wheel is disengaged
and rotation of the drive shaft stops.

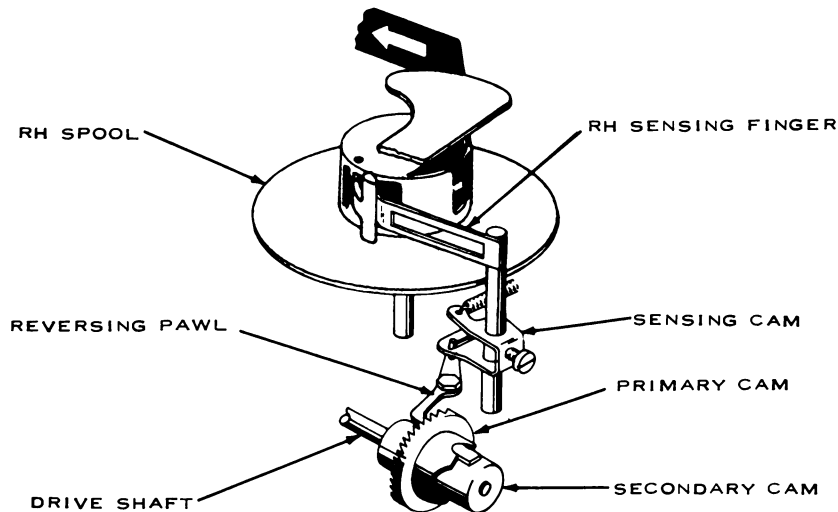
MAINTENANCE AND REPAIR

An attempt has been made in the preceding
discussion to give you considerable information
about the various mechanisms of an electric
typewriter, and to tell you how they operate
in the machine. If you have this knowledge and
understanding, you can do a much better job
analyzing and remedying casualties to the



91.66X

Figure 15-78.—LH reversing mechanism.



91.67X

Figure 15-79.—RH reversing mechanism.

typewriter, and making adjustments necessary to have all parts and mechanisms function properly.

The procedure for making a casualty analysis is the same for all makes and models of typewriters. You search for trouble until you

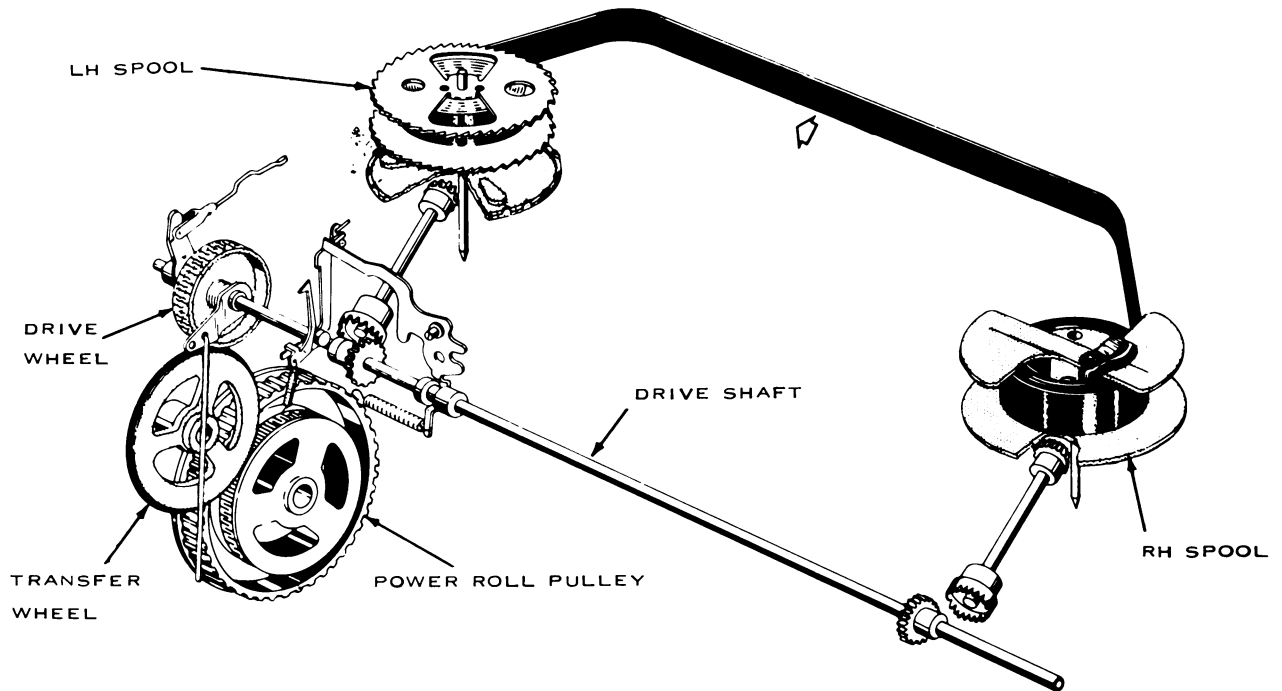


Figure 15-80.—Rapid ribbon rewind mechanism.

91.68X

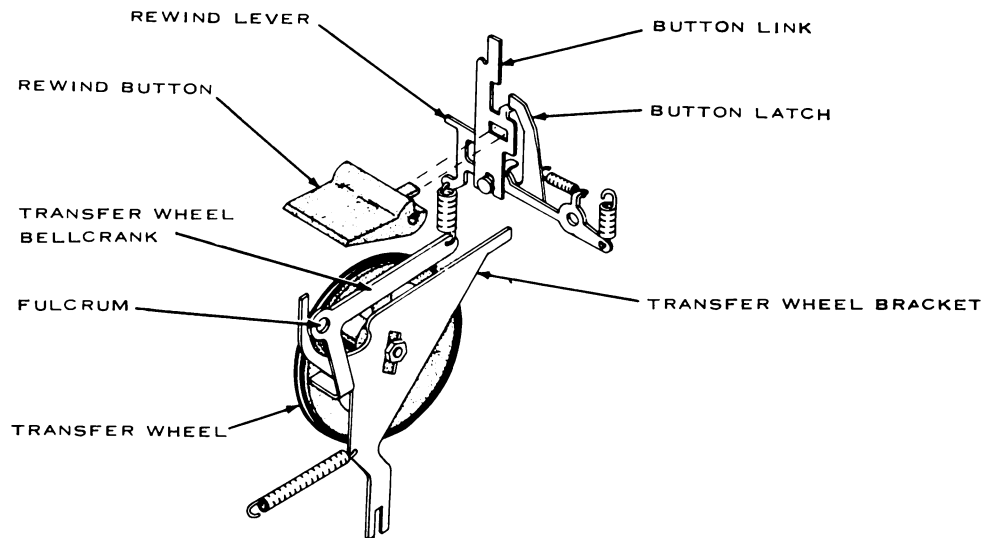


Figure 15-81.—Rapid rewind actuating mechanism.

91.69X

find it, with disassembly as necessary. Then you effect repairs or replace parts, and make adjustments. Here is where the difference arises in making repairs to an electric typewriter (s).

Parts in different makes and models of machines are different, and adjustments vary accordingly.

Additional information concerning the disassembly, cleaning and repair, reassembly and

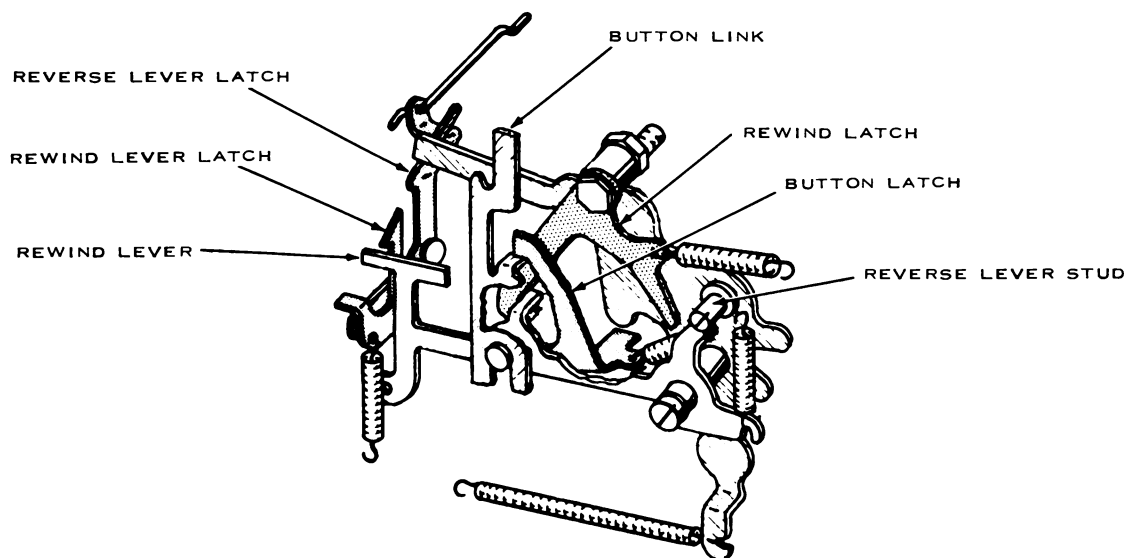


Figure 15-82.—Rewind mechanism latched.

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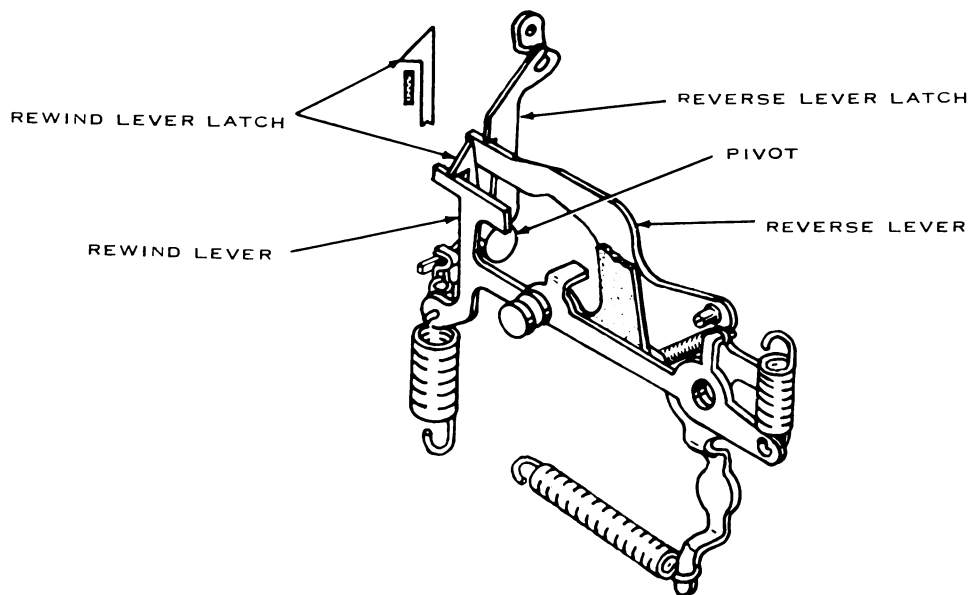


Figure 15-83.—Rewind lever latch.

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oiling, and adjustments of electric typewriters can be obtained from either the manufacturer's

technical manual for the specific unit or Instrumentman 1 and C, NavPers 10194-B.

CHAPTER 16

OTHER OFFICE MACHINES

In order to advance in rate, you must be able to clean the cylinder, change the segment roller, adjust strippers, belts, static eliminators, and feed tray and guides on fluid and stencil-process machines. In addition, you will be responsible for routine maintenance of component parts of direct process duplicators. You must also be able to analyze and remedy casualties and replace faulty parts of stencil process machines, and fluid, spirit, and direct process duplicators.

In addition to being able to perform the practical factors required for advancement in rate, you must know the nomenclature, function of parts, tools, and definitions of terms associated with the repair of office machinery such as calculators, adding machines, stencil process machines, and duplicators. In order to cover the qualifications for advancement in rate adequately, these machines are all discussed in this chapter.

REPRODUCING MACHINES

A great many machines have been developed for the purpose of reproducing written or printed documents, drawings, photographs, and similar materials. Since these machines operate on a number of principles, and since they are manufactured by a number of companies, the classification of these machines is often complicated and sometimes very confusing.

To begin with, we must make a distinction between **DUPLICATING MACHINES** (also called **DUPLICATORS**) and **COPYING MACHINES** (also called **COPIERS** or **QUICK-COPY MACHINES**). Duplicators are machines that make copies from a specially prepared master or stencil. Copiers are machines which can make copies of things that are NOT specially prepared as masters. Copiers can make copies of letters, typewritten or printed pages, drawings, photographs, and even solid objects—although it must be noted

that not all types of copiers can do all kinds of copy work. Some copiers also use a master; however, these machines are still classified as copiers because a master is not essential to the process.

In general, duplicators are used when it is necessary to make a large number of copies and copiers are used when a smaller number (1-15) of an already existing document or drawing is required. However, this distinction may not always hold true; some copiers are now capable of making a large number of copies at a high rate of speed.

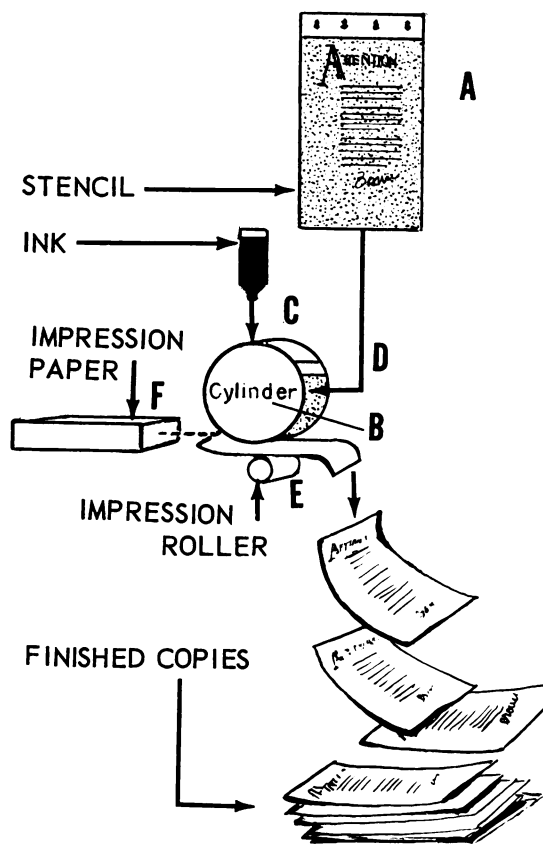
The reproducing machines discussed in this chapter are the stencil process machines, the ditto and fluid process duplicators, copying machines and the addressographs. These machines, as well as typewriters, are used extensively in various offices aboard ship; and the instrument shop is responsible for their repair and maintenance.

STENCIL PROCESS MACHINES

There are many makes and types of stencil process machines, but they are essentially the same in basic construction; and if you learn how one is constructed and how it operates, you will be able to understand how any similar type machine operates. For this reason, only one type of stencil process machine is discussed in this rate training manual; the A.B. Dick Company Model 438.

The stencil process of printing consists of four primary components: the stencil, the impression paper, the mimeograph machine, and the ink.

Figure 16-1 illustrates the parts and operating principle in simplified form. At the top of the illustration is the stencil, A, which is prepared on the typewriter. Artwork is drawn on stencils with a hand stylus, as a rule. The



6.4

Figure 16-1.—Mimeograph principle.

typewriter or the stylus cuts the stencil so that in operation the ink passes through that part which has been cut.

The cylinder of the mimeograph is represented at B. Before beginning operation, ink is poured into this cylinder through an opening (point C). The stencil is attached to the circumference of the cylinder D, which is then revolved. Below the cylinder is a roller E, which revolves in the opposite direction from D. Paper from a pile F is aligned and fed into the machine one sheet at a time by the retainer and feed mechanisms. As the paper passes between the roller and the cylinder, it comes in contact momentarily with the stencil and receives the impression from the ink passing from inside the cylinder out through the stencil openings.

Construction and Operation

The A.B. Dick Company Model 438 stencil process machine, used in this section for

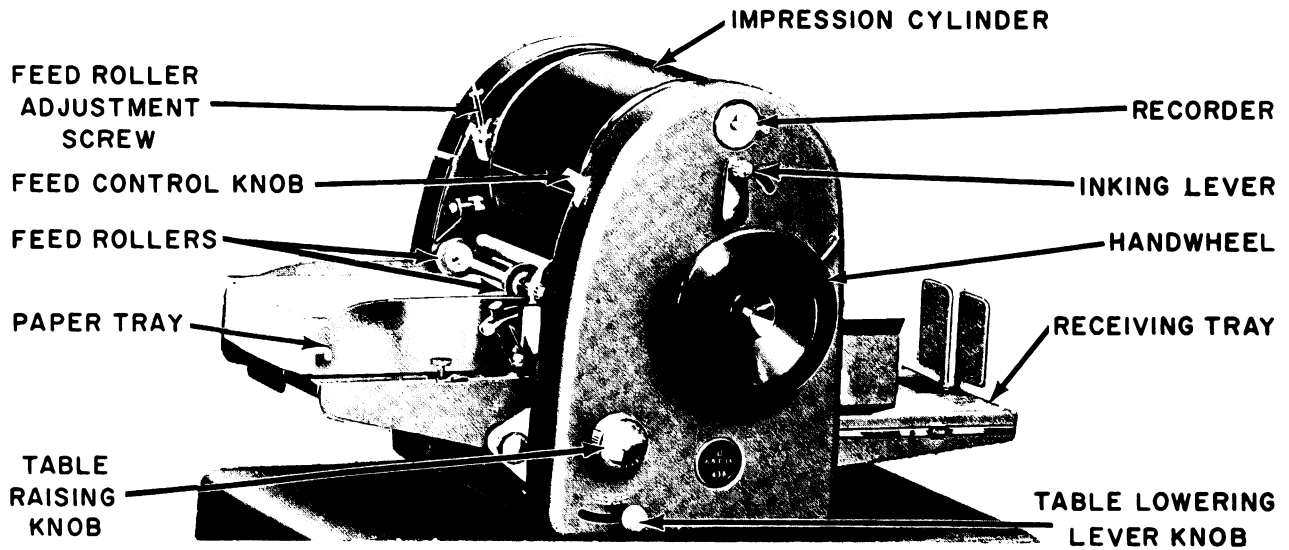
illustrative and discussion purposes, is illustrated in figure 16-2. The machine (fig. 16-2) has an ink cylinder of conventional design which can be removed easily by unlocking a lever on the cylinder shaft. The rubber impression cylinder is spring loaded and has adjusting screws for varying the spring tension. The feeder is of the friction pusher type with dual feed rollers. Roller pressure can be adjusted by a thumb screw. The feeder table raises automatically and feeds all sheets of paper placed on it. The feeder arm, however, can be raised and locked out of the way to allow hand-feeding of the machine.

The machine is equipped with gear covers, and a cylinder brake which holds the cylinder in any desired position. An interlocking device incorporated in the brake prevents the motor from being turned on while the brake is engaged. There is no shield over the stencil cylinder, but the moving of this cylinder does not present much of a safety hazard, if any.

Study figure 16-3, which illustrates a right front view of a Model 438 mimeograph machine with the covers removed. This shows many of the mechanisms and parts in the operating position; when you are studying about a particular mechanism or part, refer to this illustration to see how it fits into the machine. If you do not find a particular part in figure 16-3, refer to figure 16-4, which shows a left rear view of the same machine with the covers removed. Compare other illustrations shown in the next sections with figures 16-3 and 16-4 to get a better understanding of the functioning of all parts in the machine. This understanding will help you to service the machine properly.

FEED ROLLER MECHANISM.—The feed roller mechanism of the Model 438 mimeograph is illustrated in figure 16-5. When the truck (disk), which rolls on the feed raising cam fastened to the gear assembly, travels to the low portion of the cam, the feed raising power lever pivots clockwise. The lower end of the power lever then permits the feed raising lever assembly to pivot counterclockwise and lower the feed rollers into contact with the impression paper. Note the pressure control knob and spring, which enable you to control the amount of pressure exerted by the feed rollers on a stack of paper on the feed table.

FEED ROLLER FORWARDING MECHANISM.—Study the feed roller forwarding mechanism shown in figure 16-6. As the truck



61.56X

Figure 16-2.—A. B. Dick Model 438 mimeograph.

illustrated rides to the high position of the cam on which it operates, the forwarding lever pivots counterclockwise and pulls on the connecting link to the chain belt and also on the belt itself, turning the feed driving sprocket on which the belt fits.

As the feed driving sprocket turns counterclockwise, the large driving gear fastened to it turns counterclockwise and turns an idler gear meshed with it clockwise. The idler gear, meshed with the gear on the feed roller shaft, turns that gear counterclockwise. The feed rollers, secured firmly to the feed roller shaft, turn counterclockwise and carry the sheet of mimeograph paper on which they rest into the machine. When the truck rides to the low of the cam shown on the drive gear, the tension of the spring illustrated returns to its rest position and reverses the cycle.

OSCILLATING AND SEGMENT ROLLER MECHANISM.—Study the mechanism which controls the oscillating and segment roller mechanism in figure 16-7. When the feed rollers feed a sheet of paper into the machine against the paper stops, the truck of the oscillating roller power lever rides high on the contour of the cam on the drive wheel and holds the oscillating rollers in a position with their smooth sides up.

The low part of the cam illustrated allows the oscillating power lever to pivot clockwise. The

oscillating roller return spring then unwinds and turns the oscillating rollers until the leading edges of their serrated portions are below the paper. The rubber segment rollers then move down to grip the paper, and the paper stops and feeler pins move down to permit the paper to go forward.

As the truck of the oscillating roller power lever rolls to the high part of the cam, the power lever pulls up on the connecting link to the gear segment and causes the gear segment to pivot counterclockwise, turning the oscillating rollers clockwise and winding the spring. The paper is now firmly gripped between the rubber segment rollers and the oscillating rollers and is accelerated to the speed of the cylinder and delivered to the crotch of the cylinder and impression roller. The segment and oscillating rollers maintain contact with the paper until its leading edge is moved forward about 1/4 inch beyond the crotch.

SEGMENT AND IMPRESSION ROLLER OPERATION.—When a sheet of paper is fed in against the paper stops, the paper blocks the full rise of the feeler pins. As the cylinder turns, the high part of the cam (fig. 16-8) pushes on a truck on the end of the roller shaft arm and causes the roller shaft arm to pivot toward the rear of the machine, at which time a spring pulls a latch free from the roller stop shaft. Study the illustration.

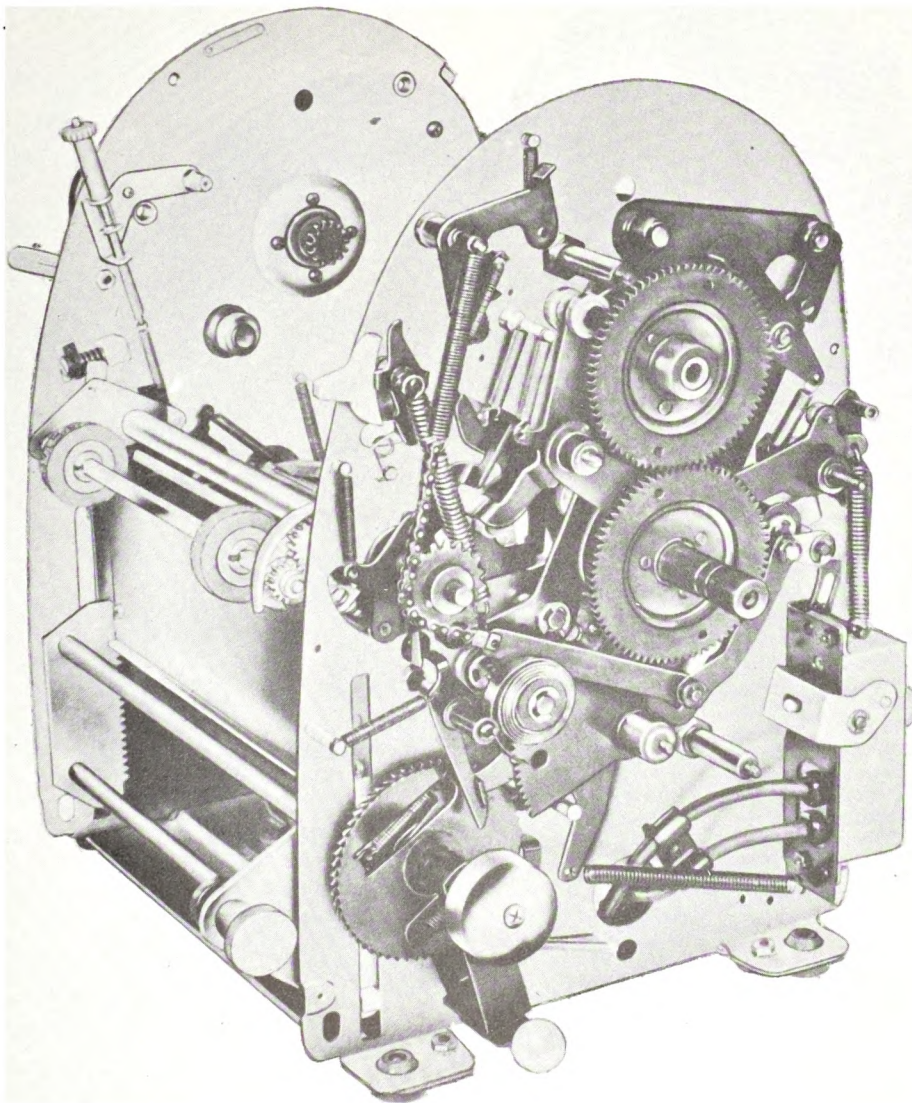


Figure 16-3.—Mechanism of a mimeograph (right-front view).

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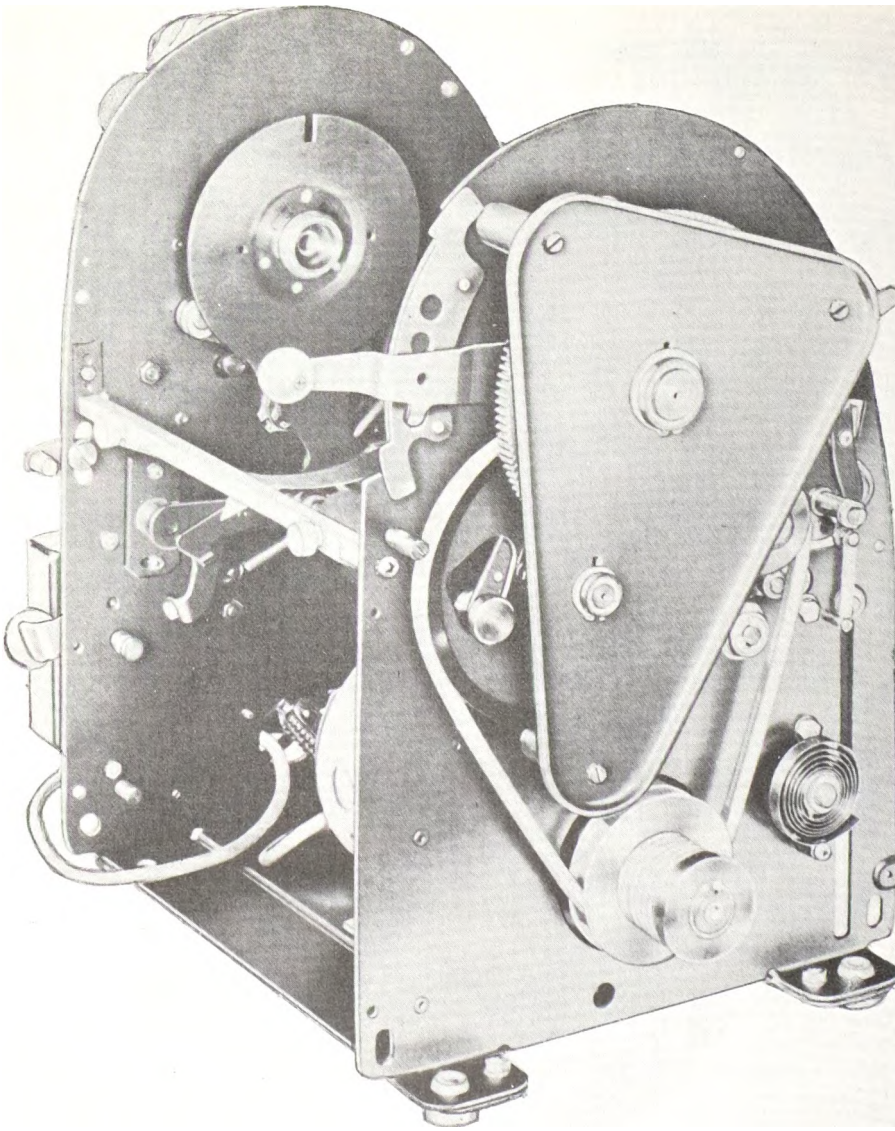
The low part of the cam permits the roller stop shaft to pivot forward, and the two springs connected to the segment roller levers pull the segment rubber rollers down to grip the paper. Springs attached (fig. 16-9) to levers on the ends of the impression roller pull up the two levers and lift the impression roller into contact with the cylinder.

Study the manufacturer's technical manual to learn how this mechanism works when the paper does not feed to the paper stops.

Care and Maintenance

The remainder of this section is concerned with the care and maintenance of stencil process machines. All details are not discussed, but they are given in the manufacturer's technical manual for the specific make and model of each machine.

When the stencil process machine is not in use, cover the ink pad of the cylinder with two thicknesses of mimeograph paper and cover this with the backing sheet of a stencil. The paper



61.58X

Figure 16-4.—Mechanism of a mimeograph (left-rear view).

absorbs the excess ink, and the backing sheet keeps out dust and air. The cylinder should not be rotated when the machine is in an inoperative status. To do so, causes air movement that dries the ink pad. If the machine is stowed with brake locked and cover in place, the temptation to turn the cylinder will be avoided. (NOTE: When the mimeograph is idle, the cylinder should be left with the ink pad side up.)

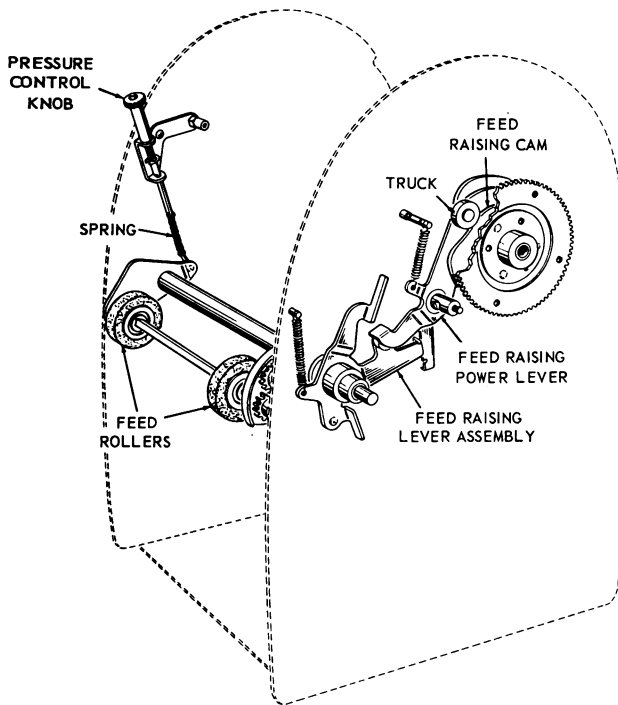
Operate the ink distributor regularly and frequently during runs, and you will have more

even distribution of ink and clearer impressions.

Machines should not be located in direct sunlight or too near a radiator. Heat may tend to cause ink leakage.

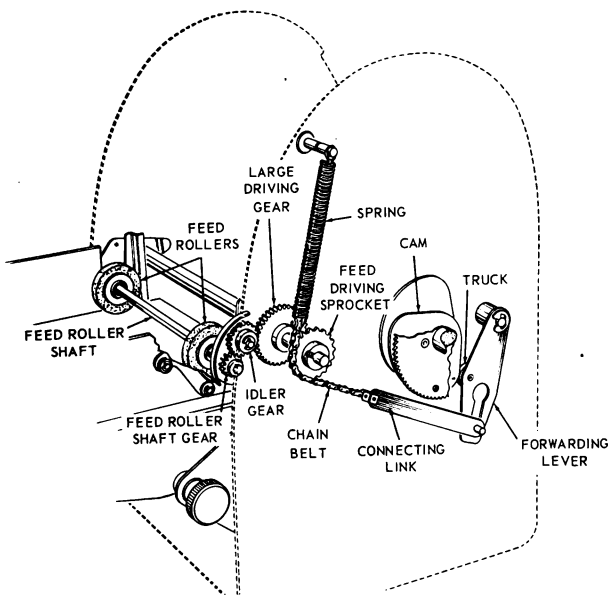
Care should be exercised to keep the Mimeograph level. Otherwise, ink may leak or copy may be weak on one side of the sheet.

REPLACEMENT OF SEGMENT AND IMPRESSION ROLLERS.—The segment and



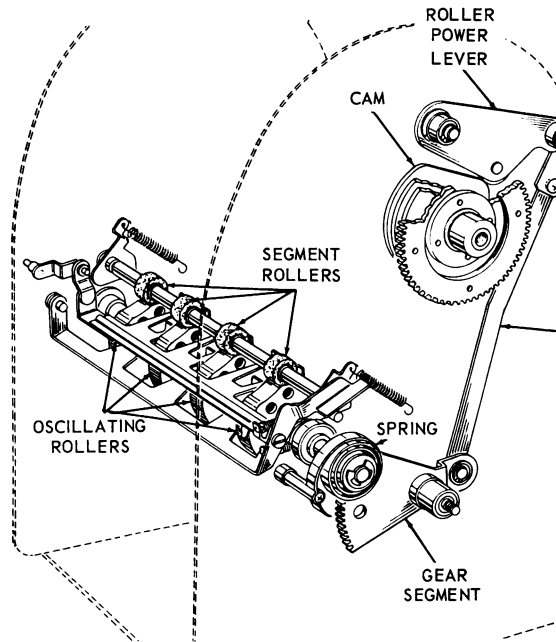
61.59X

Figure 16-5.—Feed roller mechanism.



61.60X

Figure 16-6.—Feed roller forwarding mechanism.



61.61X

Figure 16-7.—Oscillating and segment roller mechanism.

impression rollers of the A.B. Dick Model mimeograph are shown in figure 16-8. Note position of the rollers in the machine. Before you can replace old rollers, you must remove them from the machine. The procedure for doing this is a sequential process fully explained in the manufacturer's technical manual for the machine. Remove all parts of the machine necessary to get to the rollers; put all screws and small parts where they will not be lost.

After you get the new rollers installed in the machine, make necessary adjustments to them to function properly. The adjustment of the impression roller should be such that there is approximately 0.005-inch end play. The roller should so roll over the stencil that there will be no creeping of the stencil to either side during the operation. There is an adjustment plate attached to each lever of the impression roller (fig. 16-9). Note the adjustment slot for the bottom screw. Follow the details for adjustment listed in the manufacturer's technical manual for both segment and impression rollers.

ADJUSTMENT OF FEED TRAY GUIDES.—The feed tray for the Model 438 mimeograph is illustrated in figure 16-10. The

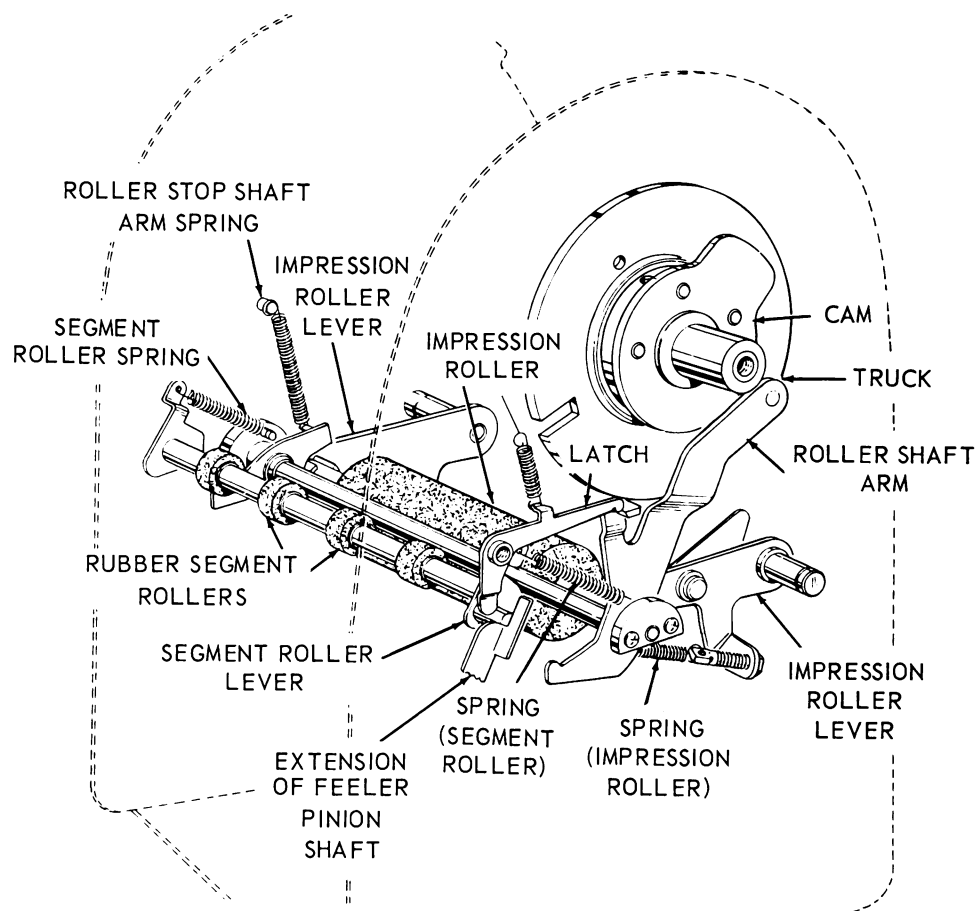


Figure 16-8.—Segment and impression roller mechanism.

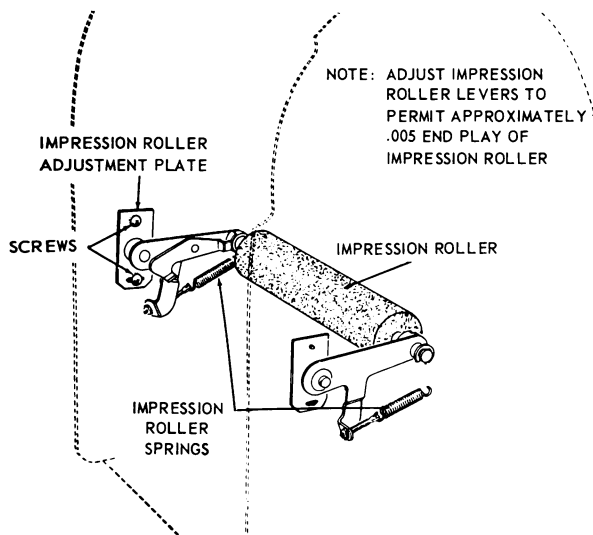
61.62X

part of the machine is shown to indicate where the feed tray is fastened to the machine, at A and B. There is an adjustable retainer paper rail for each side of the tray. These rails are held in position by a paper separator rod which runs through the middle of the tray. A retainer rail adjusting screw holds the rail in the desired position. A separator guide is provided with each rail. A paper support (adjustable) slides into the front part of the feed tray. (Note the figures on the scale to indicate inches in fig. 16-10.)

Instructions for adjusting the feed tray are given on a plate fastened to the top portion of the tray. Most adjustments you will have to make consist of placing the retainer rails in the proper position for handling paper of different widths and of adjusting the front paper support to handle

paper of different lengths. Always follow the manufacturer's instructions for making any adjustments.

ADJUSTMENT OF STRIPPERS AND STATIC ELIMINATOR.—Strippers are curved metal strips which are fastened to the rear part of a mimeograph adjacent to the cylinder to remove sheets of paper from the stencil. See figure 16-11. Note the thumb adjustment screws which hold the strippers in place. Horizontal slots in the perpendicular rear portion of the strippers permit right and left adjustments of the strippers by merely loosening and tightening the screws. If these strippers are properly curved, as shown, and then adjusted to the right or left as necessary to ensure proper contact with different sizes of paper, they will function satisfactorily.

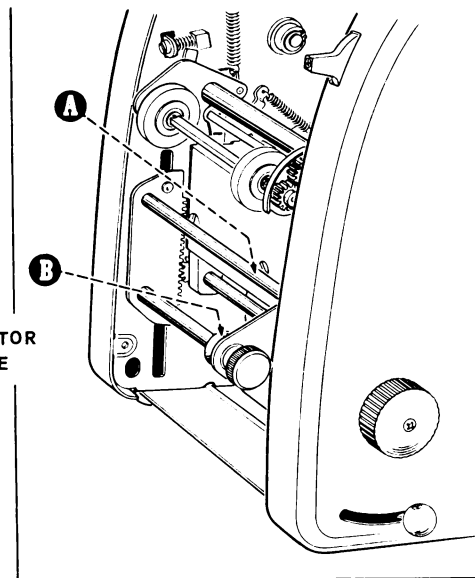
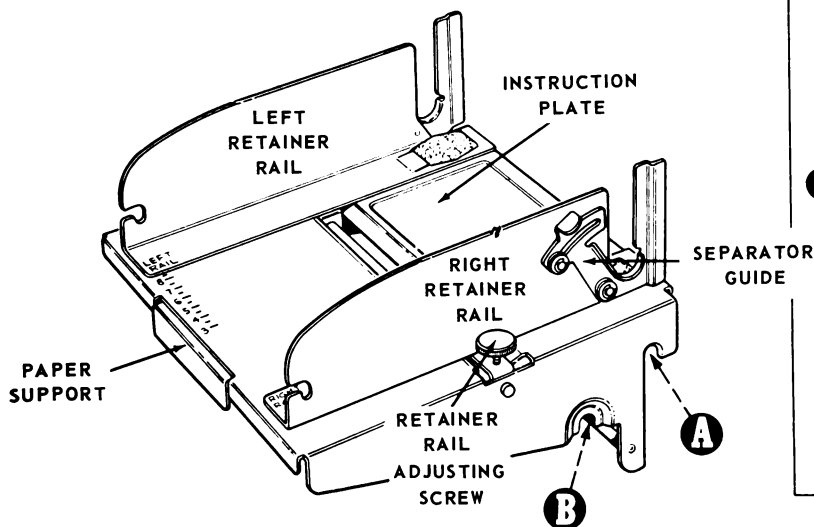


61.63X
Figure 16-9.—Adjustment of impression roller.

place by a metal clamp on top of a metal plate secured to the back of the receiving tray, as shown. The eliminator should be so positioned that it will contact the paper.

ADJUSTMENT OF BELT.—The adjustment of the belt to a motor is generally accomplished by adjustment of a movable pulley. On the Model 438 mimeograph, however, the adjustment of the belt is accomplished in a different manner. Study figure 16-12 as you read the procedure for making the adjustment. When the belt to the motor of this machine is properly adjusted, the duplicator produces 90 to 180 copies per minute. The procedure is as follows:

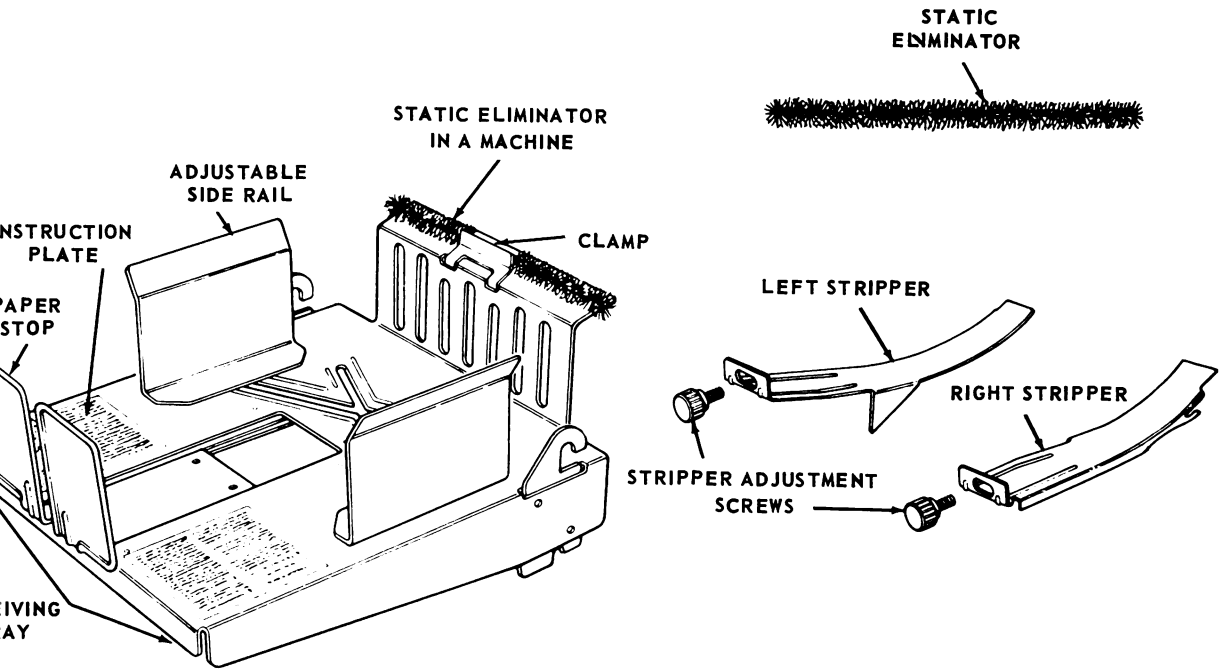
1. Move the speed control lever (fig. 16-12) down to the FAST position and check the speed of the machine.
2. Loosen the screws in the speed control plate.
3. Move the plate down to increase speed or up to decrease speed.
4. Tighten the screws.



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Figure 16-10.—Adjustment of feed tray and guides.

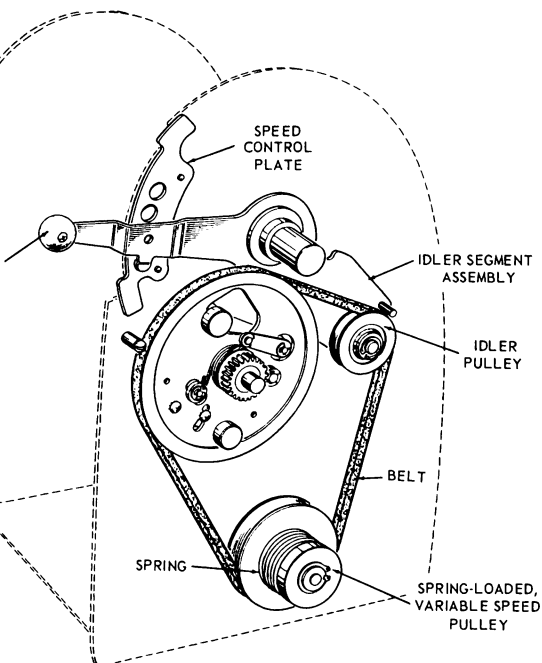
A static eliminator removes static electricity from printed mimeograph paper as it is ejected from the machine. The type of static eliminator used on the Model 438 machine is shown in figure 16-11. This type of static eliminator is held in

When the speed control lever is moved downward it causes the idler segment assembly to pivot clockwise and lower the idler pulley, creating slack in the V-belt. When tension on the V-belt is reduced, the spring-loaded front of the



61.65X

Figure 16-11.—Adjustment of strippers and static eliminator.



61.66X

Figure 16-12.—Adjustment of belt.

variable speed pulley moves toward the back and causes the V-belt to ride farther from the center of the groove in the pulley. The tightening of the belt in this manner causes the machine to run faster.

When the belt stretches too much, or becomes badly worn or broken in spots, replace it with a new one.

CLEANING PROCEDURE.—It is necessary that the cylinder, segment and impression rollers, and all working parts of a mimeograph, be kept clean and in good operating order. For cleaning lint out of the mimeograph, use a long-handled brush with soft bristles. Cleaning should be done regularly and frequently. Grease can be removed from metal parts by a solvent such as Varsol; but Varsol should not be used on the rubber segment and impression rollers, because it is injurious to rubber. Clean them with warm water and soap. Use a clean cloth to do this—do not dip them into the water.

The recommended procedure for cleaning mimeograph cylinders is as follows:

1. Remove the ink cap, tilt the reservoir, and allow the ink to drain into a container.

2. Place the cylinder into a tank containing Varsol (or Magnus 1300 cut 7-1 water) and allow to soak.

3. Remove the cylinder from the first cleaning solution and place it into a second tank filled with a mixture of Magnus 1300 cut 6-1 with water. (If not available, use Varsol.) Agitate the cylinder thoroughly. Remove excessive ink with hot water and dry thoroughly.

4. For cylinders using water base inks, follow step number one, then submerge in hot water, agitate, rinse, and dry thoroughly.

DITTO MACHINES

Besides the mimeograph machine, the Ditto machine is used extensively throughout the Navy. The hectograph and Azograph are also frequently used and operate on the same principle as the Ditto. (NOTE: Hectographs are sometimes referred to as "spirit-process" machines because they use alcohol in the ditto process.)

Unlike the mimeograph machine, the Ditto duplicator does not require a stencil or ink. Instead it uses a master. Its advantage over the mimeograph is its compact size, which is ideal aboard most small ships. Its disadvantage is that only a small number of copies (usually not more than 150) can be produced on a single master. The mimeograph can produce up to 1000 copies from one stencil.

Ditto Duplicating Process

The master copy is prepared by typing or drawing upon paper which is backed by a face-up ditto carbon sheet. The carbon transfers an image in reverse (or negative) to the back of the paper. The paper and carbon for preparing the original generally come in sets ready for insertion in the typewriter.

After preparation, the master copy is placed securely on a metal cylinder with the inked image outward. Sheets of paper are fed under a moistening roller (so they will attract dye from the master) and thence under the revolving master cylinder, from which the inked image is transferred (in positive). Each sheet of paper coming in contact with the master removes some of the carbon deposit, or dye, until the copies become too light to be legible. If the copies run at one time do not remove all the dye, the master can be saved and rerun at a future time. Ordinarily not more than about 150 clear, legible impressions are expected from one master,

including any reruns made from it (although some manufacturers now are marketing ditto carbon paper said to be good for three or four times that number of legible copies).

Color Carbon

Ditto carbon can be obtained in two or more colors. Because of this, images can be produced in different colors on the same paper. This is done by preparing a ditto carbon for each color to be printed. After the desired number of copies has been run in one color, the ditto carbon is changed and the copies are run through again, printing the second color. For general work and for economic reasons, however, purple is used almost exclusively because that dye will produce a larger number of legible copies than others.

Typing Ditto Masters

In typing ditto masters, best results usually are obtained with a medium hard typewriter platen and light to medium typing pressure. In general, the harder the platen is, the lighter the typing pressure should be, in order to avoid hollow characters on the copy. Hard platens are not recommended. If you happen to be assigned to an office that is equipped with an electric typewriter, you should type a test line on a master ditto at each typing pressure setting. Then run copies from the master and select the pressure that will give you the best results.

Corrections

In correcting errors while the master is still in the typewriter, merely turn the platen away from you until you have enough room to separate the carbon from the master and with a fine blade or sharp edged instrument, lightly scrape off the wax deposit from the imaged characters. Be sure not to scrape hard on the surface lest you cut into the master. After you have completed eliminating all the imaged characters, turn the platen back to the desired line and retype the correct characters.

Storage of Masters

Ditto masters are so made that they can be used a second time if more copies are needed later. The masters should be placed in envelopes and stored flat.

Care of Ditto Machines

Ditto machines require little or no maintenance. The machines have very few parts to oil, and it is recommended that the oiling process be done by authorized maintenance men. These duties will normally be performed by personnel in the Instrumentman rating. The only care that must be taken, where electric Ditto machines are used, is that the motor switch should be turned off when the machine is not in use. When not in use for a long period of time, the machine should be covered to prevent dust from settling inside. A regular period of maintenance should be set up with the department having maintenance responsibility. In this way you can be assured of a machine that runs well at all times.

FLUID PROCESS DUPLICATOR

As a representative type duplicating machine, the A.B. Dick Model 215 duplicator (fluid process) is discussed in this section. Before studying the parts and mechanisms of the Model 215 fluid process duplicator, illustrated in figure 16-13, review the information presented on the stencil process machines.

Parts and Mechanism

Refer to applicable illustrations as you study the parts and mechanisms of the Model 215 duplicating machine. Be sure you understand the function of all parts, so that you will understand better how to repair (or replace) and adjust them, when required.

FEED ROLLS AND STOP CONTROLS.—Feed Rolls and Stop Controls in the Model 215 duplicator are shown in figure 16-14. Note the parts in the rectangle to the right of the illustration, with an arrow pointing to their location in the machine. Study the nomenclature carefully.

When the handle of the paper separator lever is pressed down, the lever contacts the forward ends of the right and left paper separators and pivots them upward, to act as paper stops during loading.

The feed cradle may be raised or lowered manually. When you lift the cradle, the feed cradle latch locks to engage an ear on the right end of the feed roll cradle and hold the cradle assembly in the UP position. To lower the cradle and feed rolls, press inward on the feed cradle latch lock.

When the feed rolls are down (in feeding position), downward movement of the handle of the separator lever causes the left end of the lever to engage the feed roll locking lever assembly (cradle raising lever and bracket) and raise the feed roll cradle and paper separators, locking them in the UP position.

The feed pressure control lever (fig. 16-14) serves to counterbalance the feed roll and cradle assembly. When the lever is in the HIGH position, the full weight of the feed roll assembly is on the paper. As you move the lever to the LOW position, tension on the feed pressure control lever spring increases. The increased spring tension counterbalances the weight of the feed roll and cradle assembly, thereby decreasing the pressure of the feed rolls on the paper.

MOTOR DRIVE AND FEED CONTROL.—

When you turn the motor switch on, the motor drives the clutch pulley. Study the nomenclature in figure 16-15. Note the V-shaped belt over the motor and clutch pulleys.

The clutch pulley runs FREE (free wheeling) until you pull the feed control lever toward the front of the machine, which movement causes the cam lever to pivot upward and hold the clutch drive lever and hub assembly extension lever DOWN. Downward movement of this extension lever forces the actuating plate pawl DOWN, and the actuating plate and pawl spring then cause the actuating plate to pivot counterclockwise and the brake washers to disengage from the face of the clutch plate. The pulley and clutch spring continues the action by forcing the driving disk assembly to contact the disk pulley, which (with its gear) drives the cylinder gear to rotate the cylinder.

If you press the feed control (cycling) lever toward the rear of the duplicator and then release it (fig. 16-16), the movement forces the clutch driver lever down and causes the clutch pulley to revolve the cylinder once.

The selector lever spring holds the selector lever in either the 11- or 14-inch position. When the lever is in the 11-inch position, the selector lever spring lifts a pawl on the actuating lever. A stud on this pawl then moves into the path of the upper cam follower, whose spring causes the cam to follow the contour of the cylinder cam. As the upper cam follower moves to the LOW part of the cylinder cam, the actuating lever spring causes the actuating lever to pivot counterclockwise. The actuating plate and pawl spring then cause the pawl actuating plate and

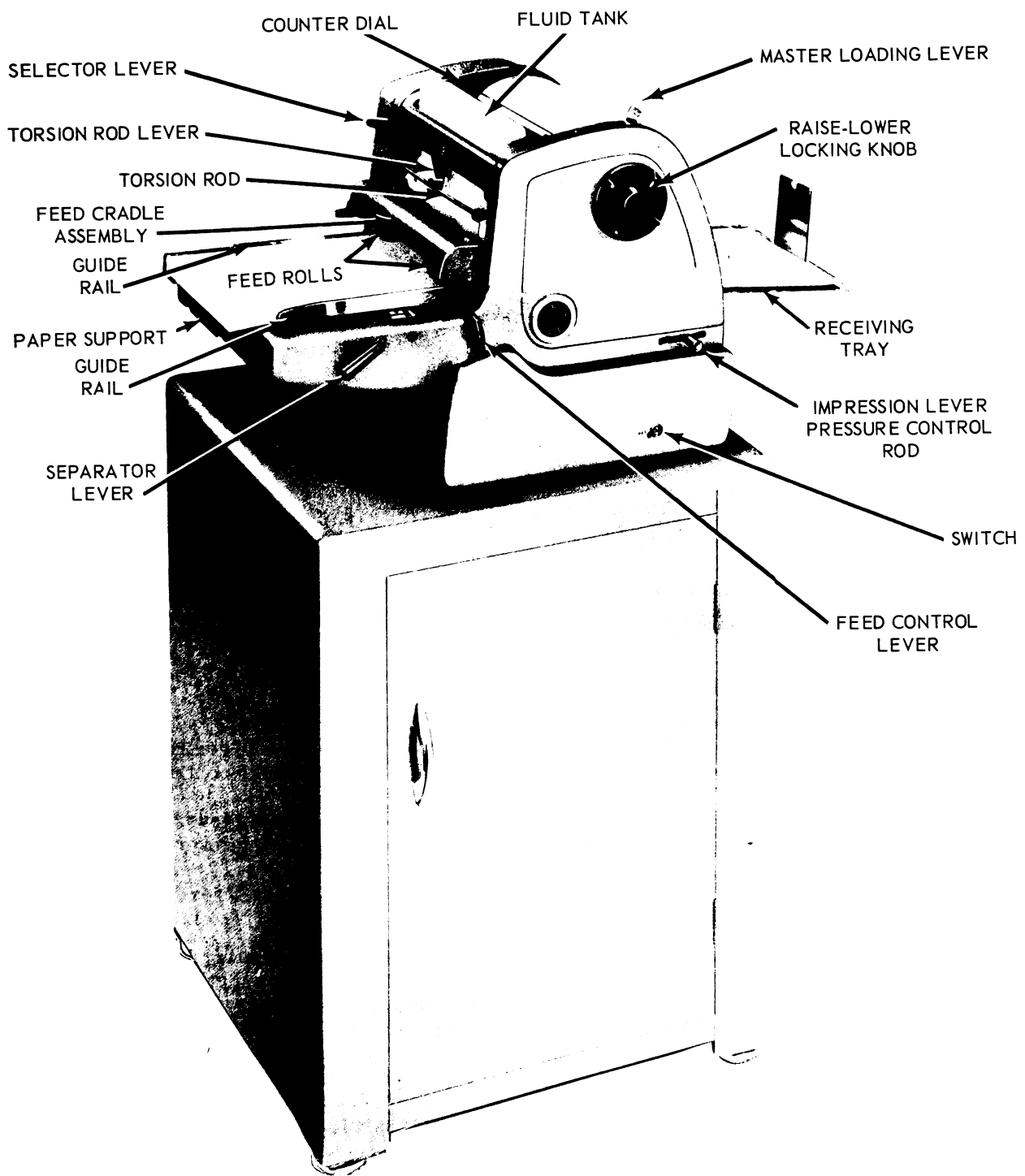
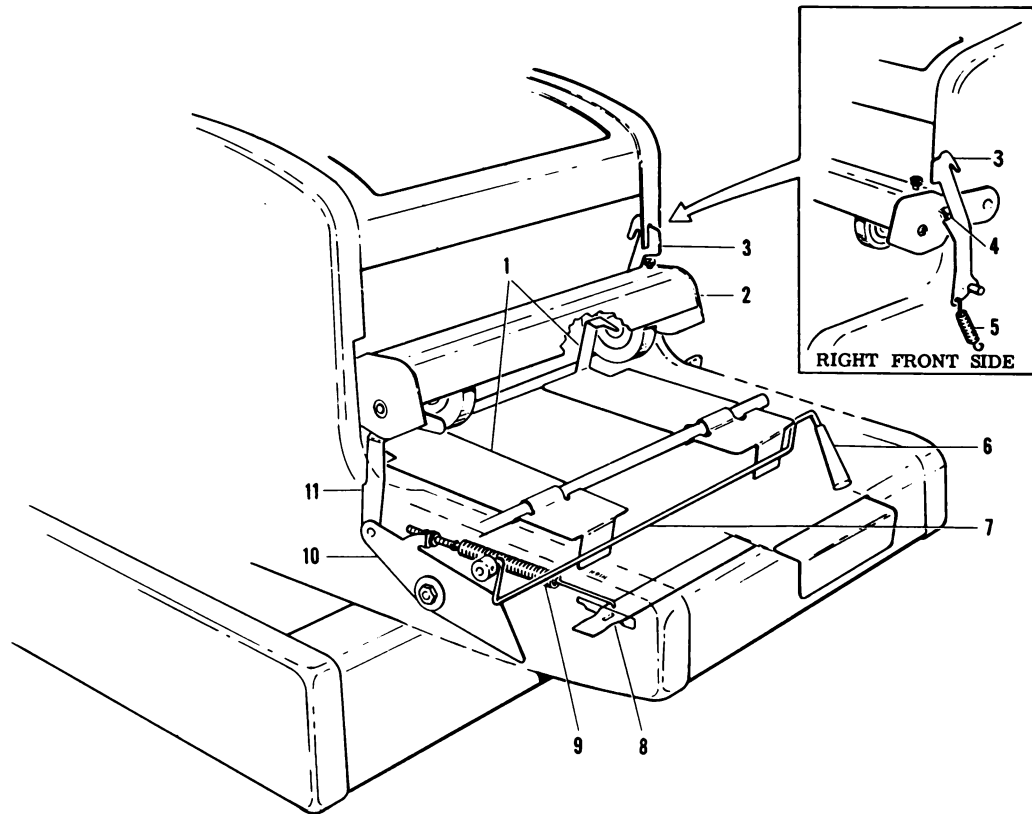


Figure 16-13.—A.B. Dick Model 215 fluid process duplicator.

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- | | |
|-----------------------------|---------------------------------------|
| 1. Paper separators | 7. Separator lever |
| 2. Feed roll cradle | 8. Feed pressure control lever |
| 3. Feed cradle latch | 9. Feed pressure control lever spring |
| 4. Ear on feed cradle latch | 10. Cradle raising lever |
| 5. Feed cradle latch spring | 11. Cradle raising lever bracket |
| 6. Separator lever handle | |

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Figure 16-14.—Feed roll and stop controls.

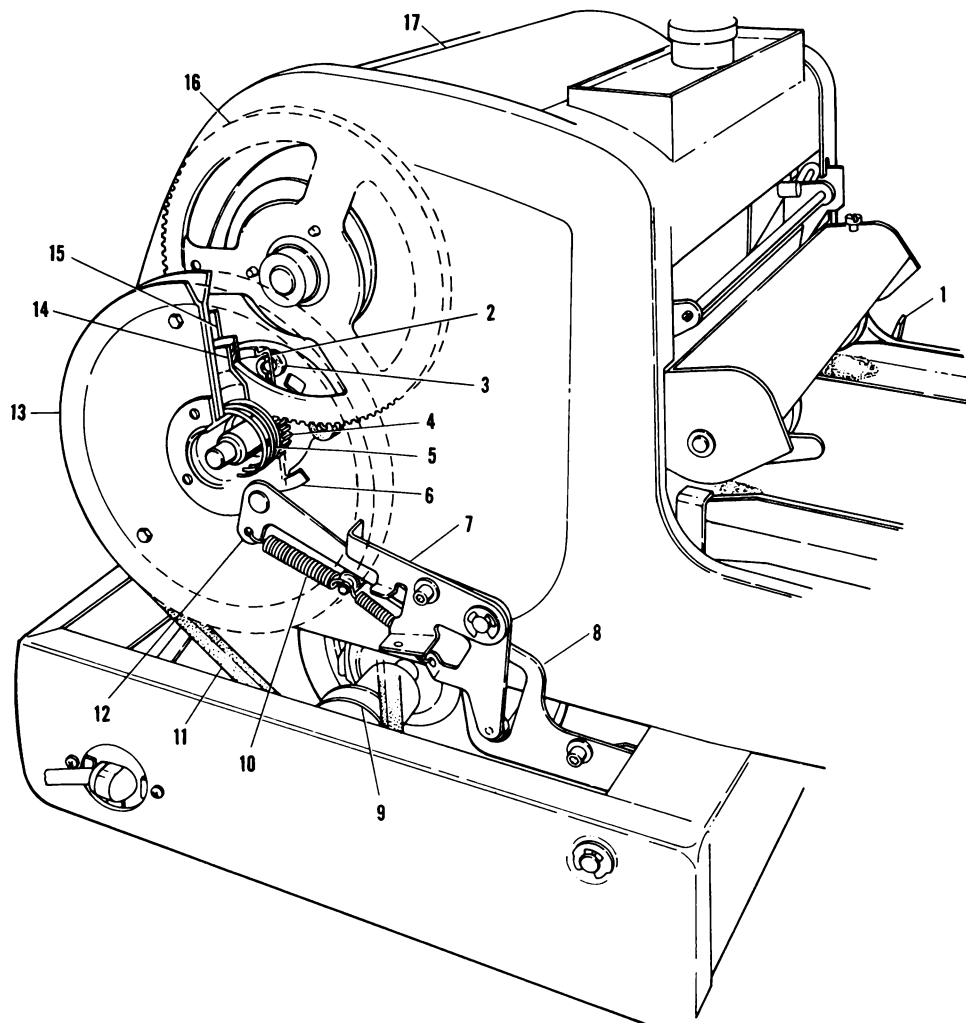
pawl assembly to move up and engage the lower end of the actuating lever.

When the upper cam follower moves to the HIGH portion of the cylinder cam, it contacts a stud on the end of a pawl on the actuating lever and causes the actuating lever to pivot clockwise. The lower end of the actuating lever, in contact with the actuating plate pawl, then pivots the actuating plate clockwise. This action disengages the clutch pulley and stops the cylinder in the 11-inch position.

When the selector lever is in the 14-inch position, the selector lever spring LOWERS

the pawl on the actuating lever. A stud on the end of this pawl then moves into the path of the LOWER cam follower, whose spring causes the cam to follow the contour of the cylinder cam. As the lower cam follower moves to the high part of the cylinder cam, it causes the clutch pulley to disengage and stop the cylinder in the 14-inch position.

PAPER FEEDING MECHANISM.—The paper feeding mechanism for the Model 215 duplicator is illustrated in figure 16-17. When the cylinder of the machine revolves, the cam groove in the



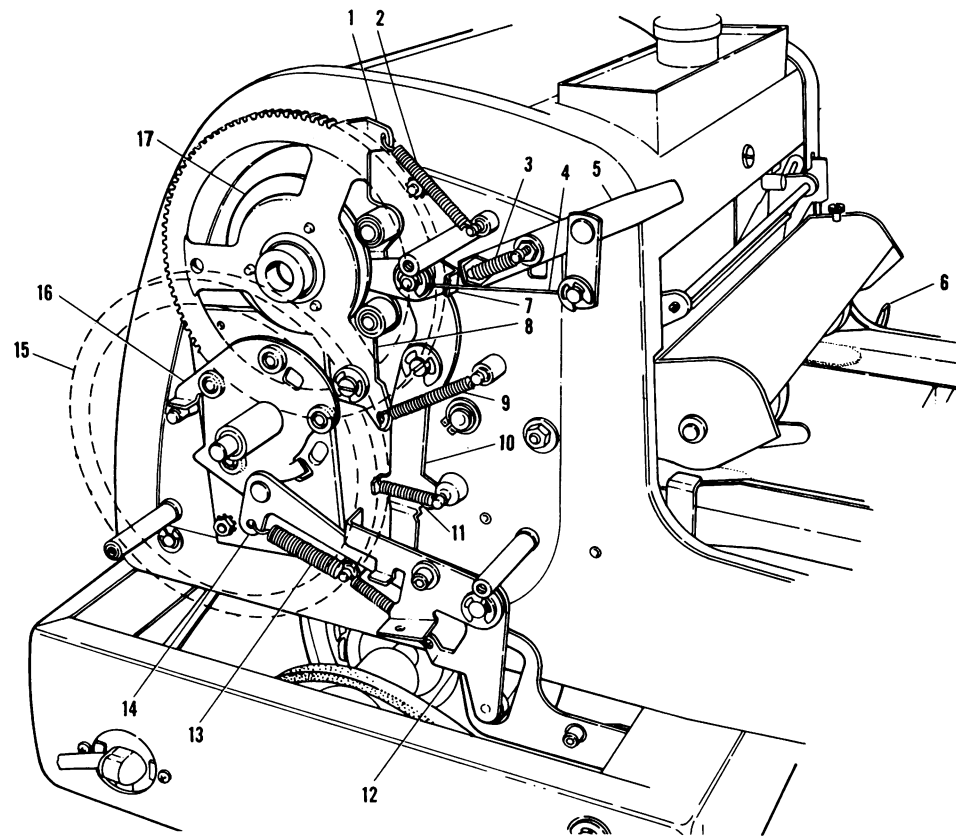
- | | |
|-------------------------------------|-------------------------------------|
| 1. Feed control lever | 9. Pulley |
| 2. Clutch plate | 10. Actuating plate and pawl spring |
| 3. Brake washers | 11. Belt |
| 4. Disk pulley drive gear | 12. Actuating plate pawl |
| 5. Pulley and clutch spring | 13. Clutch pulley |
| 6. Actuating plate | 14. Driving disk assembly |
| 7. Extension lever and hub assembly | 15. Disk pulley |
| 8. Cycling lever cam | 16. Cylinder gear |
| | 17. Cylinder |

91.79X

Figure 16-15.—Driving mechanism.

raise-lower plate causes oscillation of the moistening roller gear feed segment. As the truck of the feed segment rides to the HIGH part of the

cylinder cam, the feed segment turns the moistening roll gear, the intermediate gear, the idler gear, and the feed shaft clutch drive gear.



- | | |
|------------------------------|-------------------------------------|
| 1. Upper cam follower | 10. Actuating lever |
| 2. Upper cam follower spring | 11. Actuating lever spring |
| 3. Selector lever spring | 12. Clutch drive lever |
| 4. Cam follower spring | 13. Actuating plate and pawl spring |
| 5. Selector lever | 14. Actuating plate pawl |
| 6. Speed control lever | 15. Clutch pulley |
| 7. Actuating lever pawl | 16. Actuating plate |
| 8. Lower cam follower | 17. Cylinder cam |
| 9. Lower cam follower spring | |

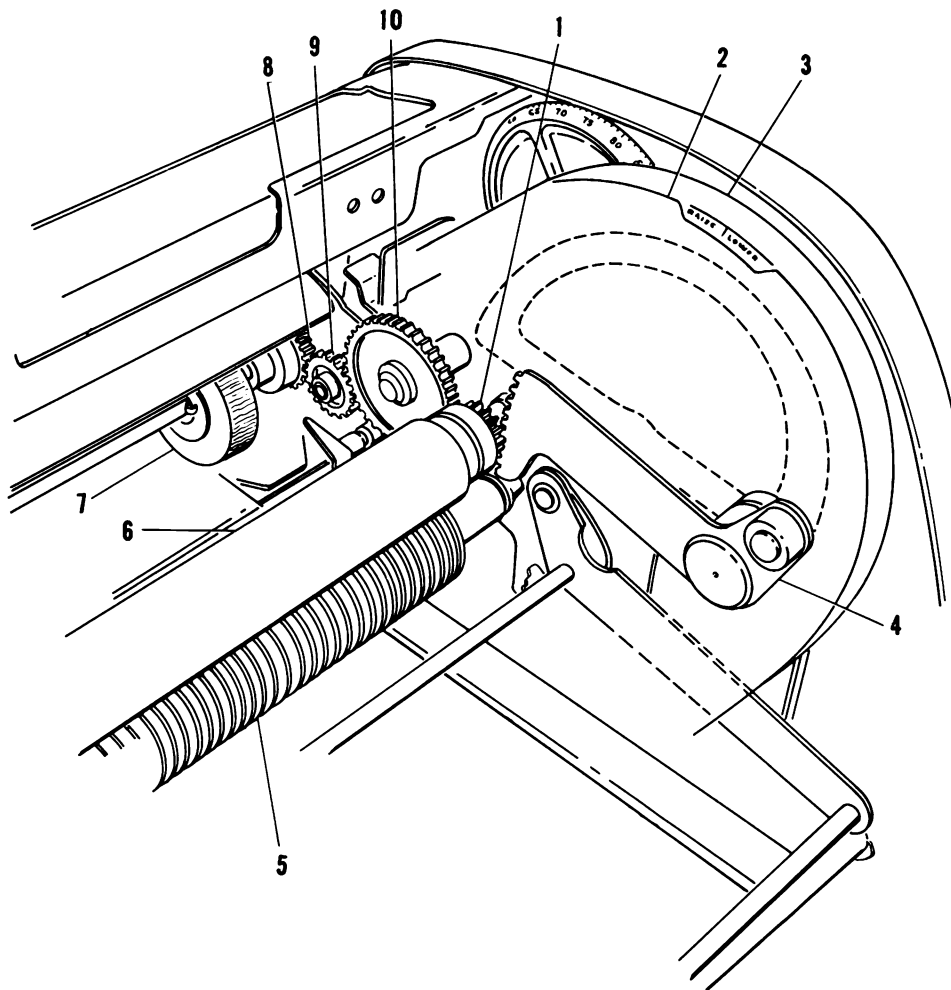
91.80X

Figure 16-16.—Feed control mechanism.

When the feed rolls revolve, they advance the top sheet of impression paper to the crotch formed by the moistening roller and the forwarding roller. The clutch assembly allows the feed segment to follow the low contour of the cylinder cam and the feed rolls then FREEWHEEL while the impression paper travels through the machine.

PAPER MOISTENING SYSTEM.—The moistening system of the Model 215 fluid process duplicator consists of the following: fluid container, reservoir assembly, wick, moisture control lever, moistening roller, and the forwarding roller. See figure 16-18.

When you invert the fluid container and insert the valve cap in the reservoir, the spring



- | | |
|-----------------------------|------------------------|
| 1. Moistening roller gear | 6. Moistening roller |
| 2. Cylinder | 7. Feed roller |
| 3. Raise-lower plate | 8. Clutch driving gear |
| 4. Roller gear feed segment | 9. Idler gear |
| 5. Forwarding roller | 10. Intermediate gear |

91.81X

Figure 16-17.—Paper feed mechanism.

valve is forced open, allowing the fluid to flow into the reservoir until the fluid level reaches the level of the valve outlet. (When the valve outlet is covered, air cannot enter the fluid tank and vacuum prevents further flow of the liquid.)

Now, if you move the moistening control (torsion rod) lever down to the ON position, the saturated wick (insert, fig. 16-18) transfers fluid to the moistening roller, which (in turn)

transfers the moistening fluid to the top surface of the impression paper.

PAPER FORWARDING MECHANISM.—When the feed rolls advance a sheet of impression paper to the crotch formed by the moistening and forwarding rollers, these rollers forward the paper to the crotch formed by the cylinder and the impression roller. As the cylinder revolves, the cam groove in the raise-lower plate

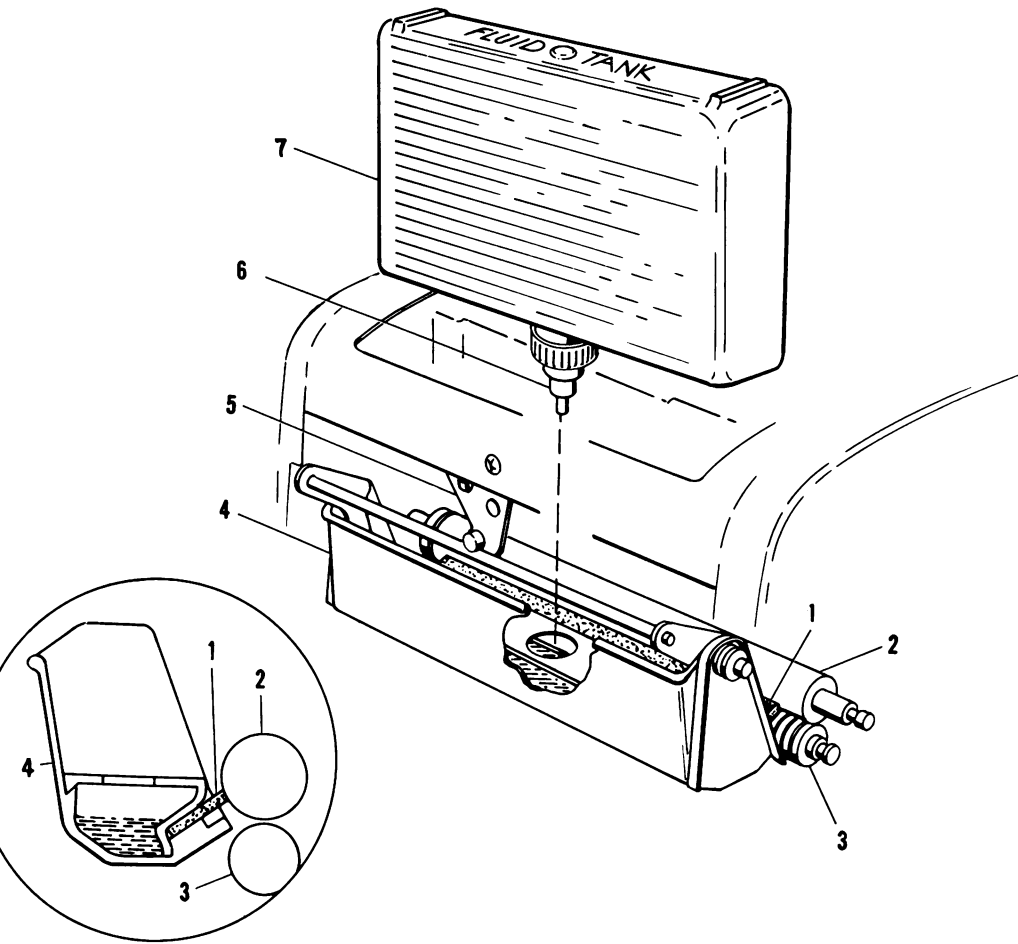


Figure 16-18.—Paper moistening system.

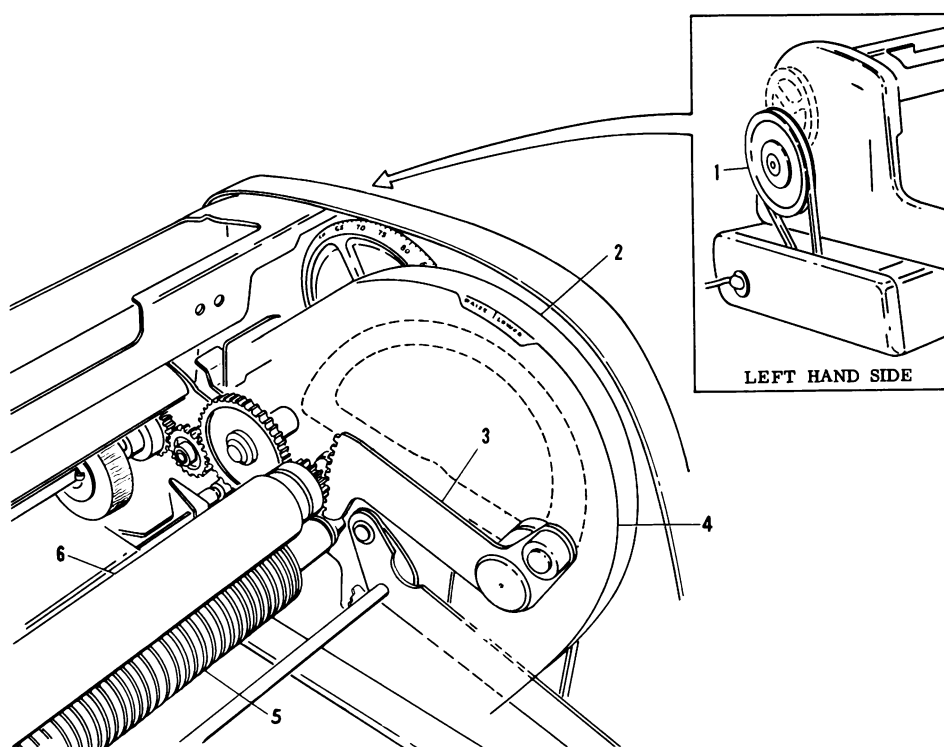
91.82X

the moistening roller gear feed segment te. As the truck of the feed segment s to the HIGH section of the cylinder feed segment turns the moistening d also the forwarding roller. See figure

lutch assembly allows the feed segment e its movement while the moistening ntinues to revolve during the passage of ssion paper through the machine. The celerated to cylinder speed by the g roller, is now gripped between the

cylinder and the impression roller, Under pres- sure by the impression roller, the moistened surface of the paper accepts a deposit from the master copy, duplicating the master. The dupli- cated copy is then delivered into the receiving tray.

IMPRESSION ROLLER PRESSURE MECHA- NISM.—Impression roller pressure is controlled by the impression roller pressure control rod, shown in figure 16-20. When the handle of this rod is in the OFF position, toward the front of



- | | |
|--|----------------------|
| 1. Clutch assembly | 4. Cylinder |
| 2. Raise-lower plate | 5. Forwarding roller |
| 3. Moistening roller gear feed segment | 6. Moistening roller |

91.83X

Figure 16-19.—Paper forwarding mechanism.

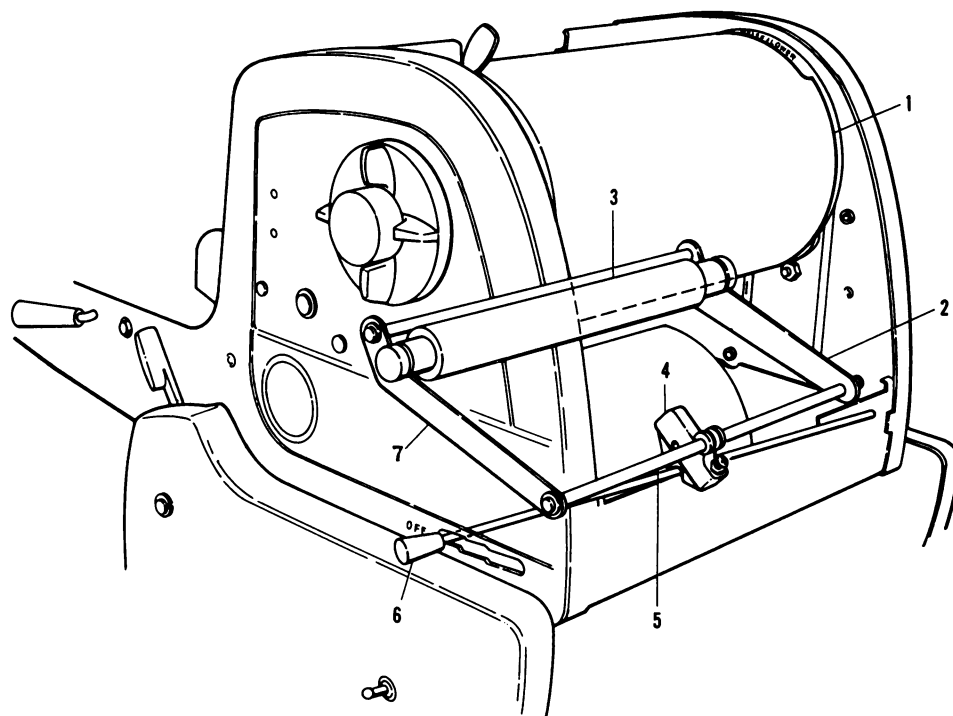
the machine, impression roller pressure is OFF. If you move the impression roller pressure control rod BACK (through elongated slot in the side frame), the compression link causes the compression link tension bar and the impression roller levers to press the impression roller against the cylinder. When you move the handle of the impression roller pressure control rod FARTHER back, you increase the impression roller pressure against the cylinder.

MASTER LOADING LEVER.—Always stop the cylinder in the 11-inch position when you attach master copies, regardless of the length. When you move the master loading lever (fig. 16-21) to the OPEN position, clamp the cylinder clamp cam upward, as illustrated. This movement of the cylinder clamp cam causes the clamp

opening lever to lift the master copy cylinder clamp to the open position to receive the master.

When you move the master loading lever to the CLOSED position, the cylinder cam clamp spring pivots the cylinder clamp cam downward. Then the master clamp springs pull the master clamp DOWN to grip the master copy.

COPY RAISE-LOWER MECHANISM.—If you turn the raise-lower locking knob counterclockwise, you can turn the cylinder to RAISE or LOWER the copy. When you turn the locking knob clockwise, a cylinder sleeve moves the cylinder to the left, where the cylinder is held firmly in contact with the clutch facing of the raise-lower plate. The adjustment is then locked in the desired position.



- | | |
|----------------------------|---------------------------------|
| 1. Cylinder | 5. Compression link tension bar |
| 2. Impression roller lever | 6. Pressure control rod |
| 3. Impression roller | 7. Impression roller lever |
| 4. Compression link | |

91.84X

Figure 16-20.—Impression roller pressure mechanism.

Disassembly and Reassembly

The manufacturer's technical manual for the A. B. Dick Model 215 duplicator shows how to disassemble the machine in numerical sequence. Small letters are also used to designate the removed parts of some units; and capital letters designate the location of some parts. This system of designating and locating parts of the machine makes disassembly rather simple.

When necessity requires that you disassemble this machine, keep the manufacturer's technical manual available for ready reference. Follow the disassembly procedure by the letters and you will have no difficulty. Use precaution to protect, and prevent the loss of, all parts. Put small parts in containers.

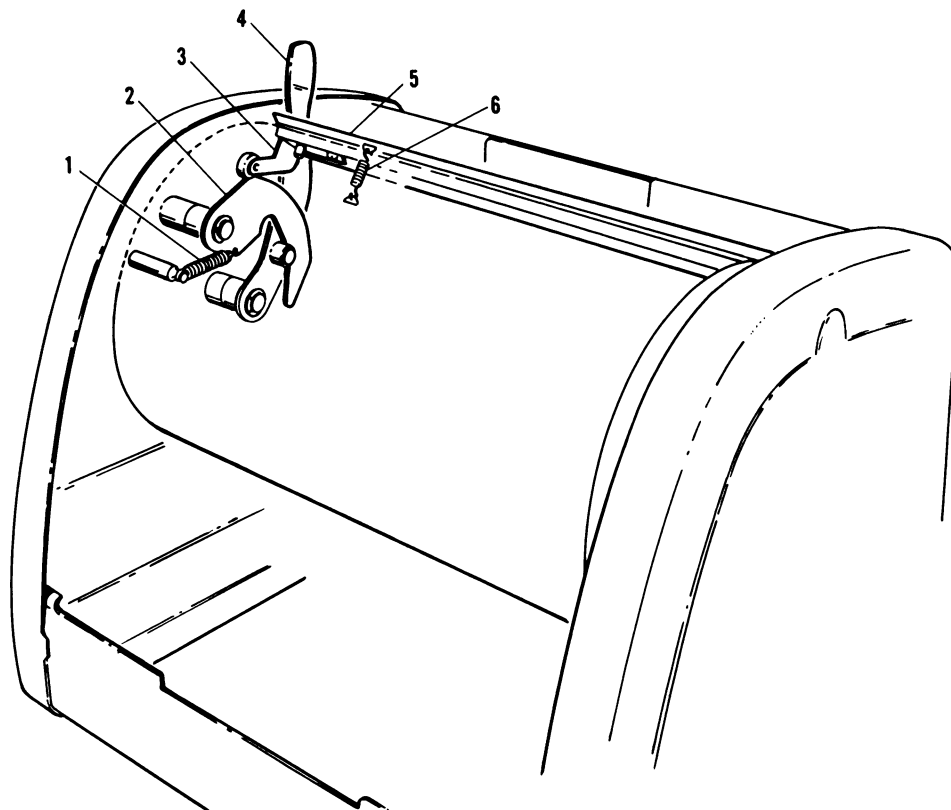
Reassembly procedure is the reverse of disassembly. Clean all parts before you reassemble

them; when necessary, install new parts. Check the illustrations in the technical manual for oil points and apply oil during reassembly. Make adjustments to the extent possible as you reassemble parts.

Mechanical Adjustments

Adjustments of the Model 215 duplicator discussed in this section are those you will be required to make in instrument shops. Read first the procedure for making adjustments on a part or mechanism; then study the illustration to find out where to make them.

FEED RAISING LEVER.—Adjust the feed raising lever as necessary to have it lift the feed rolls to the proper height for loading



1. Cylinder clamp cam spring
2. Cylinder clamp cam
3. Clamp opening lever

4. Master loading lever
5. Master copy clamp
6. Master copy clamp spring

91.85X

Figure 16-21.—Master loading lever.

impression paper on the feed table. To do this, proceed as follows:

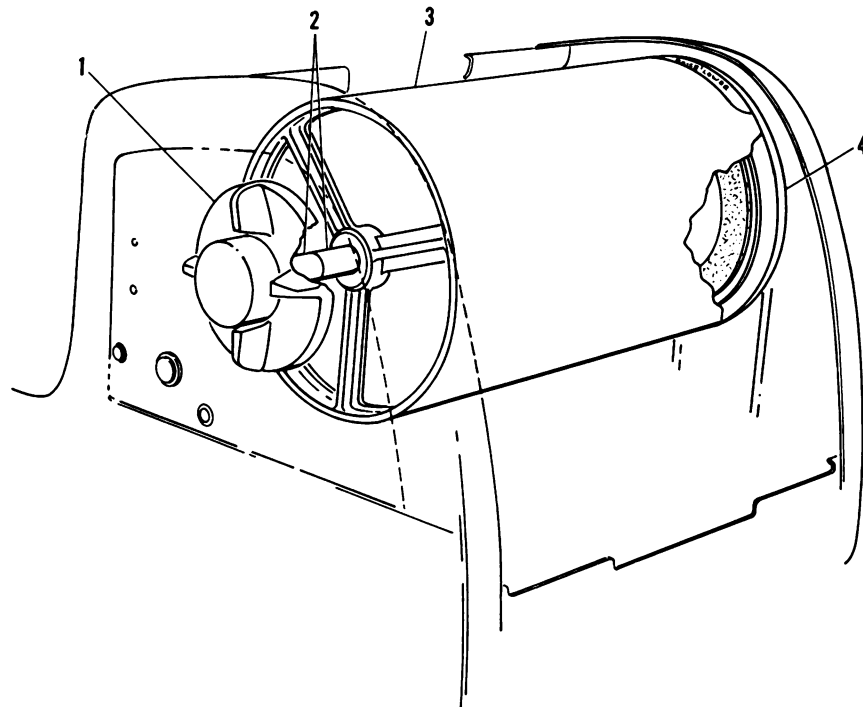
1. Lower the feed roll assembly to the feeding position (fig. 16-23).
2. Turn the separator lever down to the loading position in order to have it lock in the notch of the feed raising lever.
3. Loosen the hexagonal nut which holds the lever and bracket assembly in place and adjust the feed raising lever to the extent required to have the underside of the bracket $15/16''$ above the bare feed table, as illustrated.
4. Tighten the hexagonal nut.

FEED ROLL PRESSURE.—Pressure on the feed rolls is correct when feeding of paper into

the machine is **ACCURATE**. (Pressure control spring is properly adjusted.) To adjust the pressure control spring, do the following:

1. Put the pressure control lever in the **LOW** position. See figure 16-24.
2. Place a $7/16''$ block on the feed table under the lip of the bracket, as illustrated.
3. Put a spring tension testing scale on top of the bracket secured to the pressure control lever and press **DOWN**. If the reading on the pressure scale is **NOT** 21 ounces, turn the nuts on the adjusting screw to the extent necessary to make the reading 21 ounces.

FEED ROLLS.—To ensure the feeding of each sheet of paper **STRAIGHT INTO** the machine,



1. Raise-lower locking knob
2. Cylinder sleeve

3. Cylinder
4. Raise-lower plate

91.86X

Figure 16-22.—Copy raise-lower mechanism.

the feed rolls must be adjusted **PARALLEL WITH** the feed table. To adjust them in this manner, proceed as follows:

1. Assemble each feed roll (with friction spring) on the same flat surface of the square shaft, with the black dot on the roll facing the left side of the machine (fig. 16-25).

2. Position the paper guide rails for 8 1/2" paper.

3. Lower the feed rolls and center each roll over the cork pad on the guide rail. Study the illustration.

4. Put the pressure control lever in the **LOW** position.

5. Place a strip of paper between each feed roll and the cork pad and pull on the strips. If the pull on both strips is **NOT EQUAL**, turn the adjusting screw (illustrated) as necessary to equalize the roll pressure.

WICK ALIGNMENT.—In order to ensure uniform quality in copying, the wick of the duplicator must contact the moistening roll in a uniform

manner along its entire length. In order to get uniform pressure of the whole wick on the surface of the moistening roll, do the following:

1. At each end of the moistening roller, put a 1-inch strip of 20 lb. paper between the **DRY** wick and the roller. Study figure 16-26.

2. Push the torsion rod down to the **ON** position to apply pressure on the wick and then test the **PULL** on each strip of paper.

3. If necessary, bend the trough bracket where the resistance to your pull is **LESS**. Bend the lower end of the bracket toward the moistening roller. **CAUTION:** Use care; a **SLIGHT** bend is sufficient.

IMPRESSION ROLLER PRESSURE.—Pressure on the impression roller must be such that proper pressure can be obtained at minimum and maximum settings. To obtain correct impression roller pressure, proceed as follows:

1. Put the impression roller control rod in the **OFF** position.

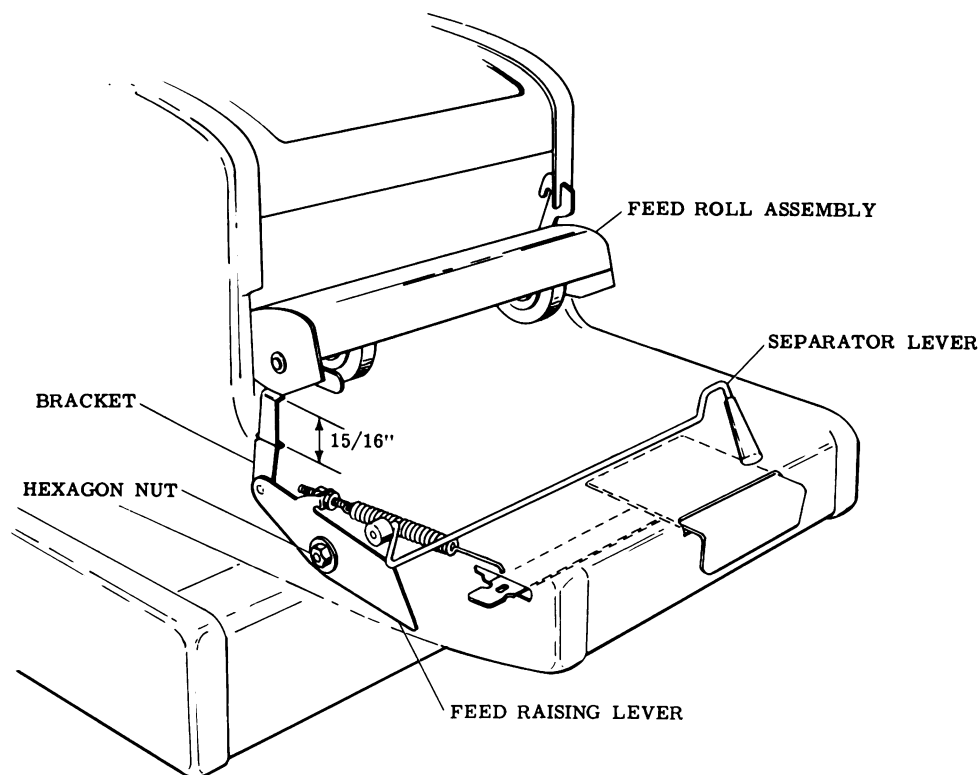


Figure 16-23.—Adjusting the feed raising lever.

91.87X

2. Loosen the locknut (fig. 16-27) and turn the adjusting screw until a slight drag takes place between the impression roller and the cylinder. Test the drag by turning the roller in the direction indicated by the arrow.

3. Hold the adjusting screw and tighten the locknut. Then recheck the drag on the impression roller.

CLUTCH ACTUATING CAM.—The clutch actuating cam is properly adjusted when it stops the cylinder with the master copy clamp in the desired position for attaching and removing master copies. You can properly adjust the cam by:

1. Positioning the cylinder raise-lower adjustment exactly at the 0 position. See illustration 16-28.

2. Placing the impression roller control rod in the medium pressure position.

3. Putting the selector lever in the 11-inch position, turning on the motor switch, pressing

the cycling lever, allowing the cylinder to stop, and turn off the motor.

4. Setting the counter dial at 0, as shown.

5. Placing the BEVELED EDGE of the cylinder at the master clamp in line with figures 94-95 on the counter dial.

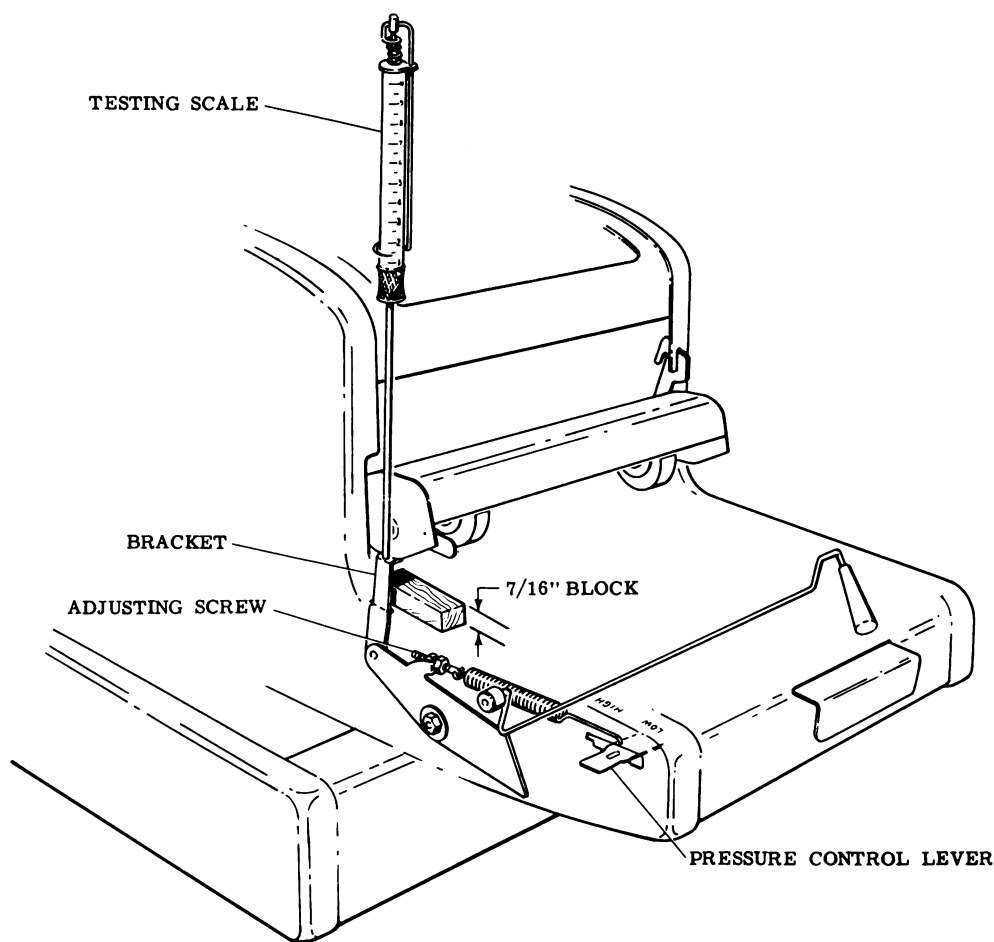
6. Pressing the cycling lever, loosening the adjustment screw on the cam, and rotating the cam in the opposite direction from the movement desired of the cylinder. NOTE: Counter-clockwise rotation increases the dimension; clockwise rotation decreases the dimension.

7. When you have the adjustment correct, tighten the screws and recheck.

CYCLING MECHANISM.—The cycling mechanism is properly adjusted when it functions satisfactorily in BOTH the single-sheet and continuous-feed positions. To make proper adjustments, do the following:

1. Loosen screws A and B (fig. 16-29).

2. Position the end of the actuating lever on the step of the pawl, as illustrated.



91.88X

Figure 16-24.—Adjusting feed roll pressure.

3. Locate the truck (roller) of the extension lever in the CENTER position of the cycling lever cam.

4. Adjust the actuating lever as necessary to have the formed ear rest on the pawl.

5. Tighten screw A and position the cycling lever as shown in the insert of figure 16-29. Note the position of the $\frac{23}{32}$ " dimension.

DRIVE BELT.—The drive belt is correctly adjusted when it has $\frac{1}{4}$ " of slack, as shown in figure 16-30. You can properly adjust the belt by:

1. Loosening the four mounting screws and positioning the motor in the position required to have the correct amount of slack in the belt.

2. Tightening the mounting screws and checking the adjustment.

When the drive belt is adjusted properly, one side of it moves $\frac{1}{4}$ " without causing any movement in the opposite side of the belt or motor pulley.

Lubrication

The A. B. Dick Model 215 duplicator is lubricated at the factory with special lubricants and will run for years under normal operating conditions without additional lubrication. However, if it is necessary during repairing or overhauling of the machine that you wash parts with solvent or immerse the machine in solvents

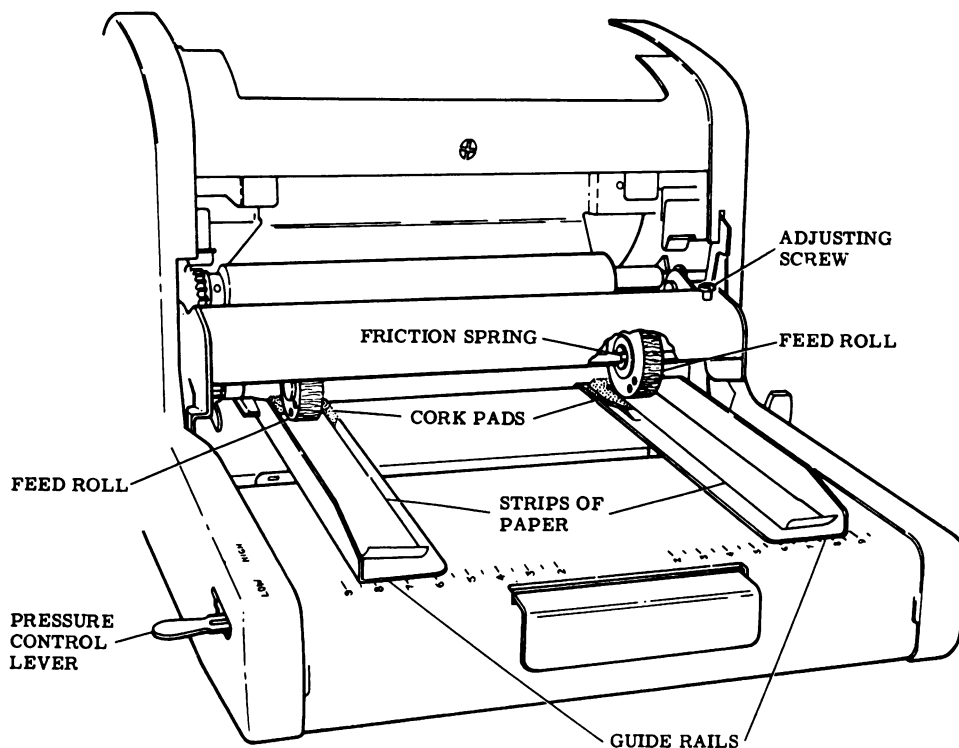


Figure 16-25.—Adjustment of feed rolls.

91.89X

for cleaning, oil all parts which require oil with factory-recommended lubricants. Check for the location of oil points on illustrations in the technical manual for the machine.

Table 16-1 lists the parts of the duplicator which require lubrication and gives the recommended procedure for lubricating. Each part is numbered, and each part is indicated by the same number used in the table.

COPYING MACHINES

Copying machines are being used increasingly aboard ship and at shore stations; therefore, the Instrumentman should know something about them. Some of these machines are in the Print Shop and Instrumentmen should check with the senior men there if problems arise concerning maintenance and repair. (NOTE: An Instrumentman may be assigned to an AD, AR, and AS type ship; all these ships have Print Shops.)

However, the rapid increase of fast-copy machines and their widespread use has created security problems and increased operating costs

needlessly. These machines permit quick easy reproduction of uncontrolled classified material, leave latent impressions on reproduction equipment, and create excessive waste material which can contribute to compromise of classified information. A few of the many misuses and abuses that contribute to high operating costs are: using a copier in lieu of making one or two carbons at the time of typing; copying blank forms or publications which are available from stock rooms; making more copies than are needed on the mere possibility that extras may be required; using a copier for long runs or long tapes that should have been done by a Print Shop. Controls should be established to prevent unnecessary costs and to prevent security abuses in the use of the fast-copy machines.

Machines utilizing the dry electrical copying process, such as Thermofax and Xerox, are used throughout the Navy. Letters, drawings, and forms may be reproduced in minutes, and with some models in seconds. There are so many types of these machines, all differing slightly, that it is impracticable to describe

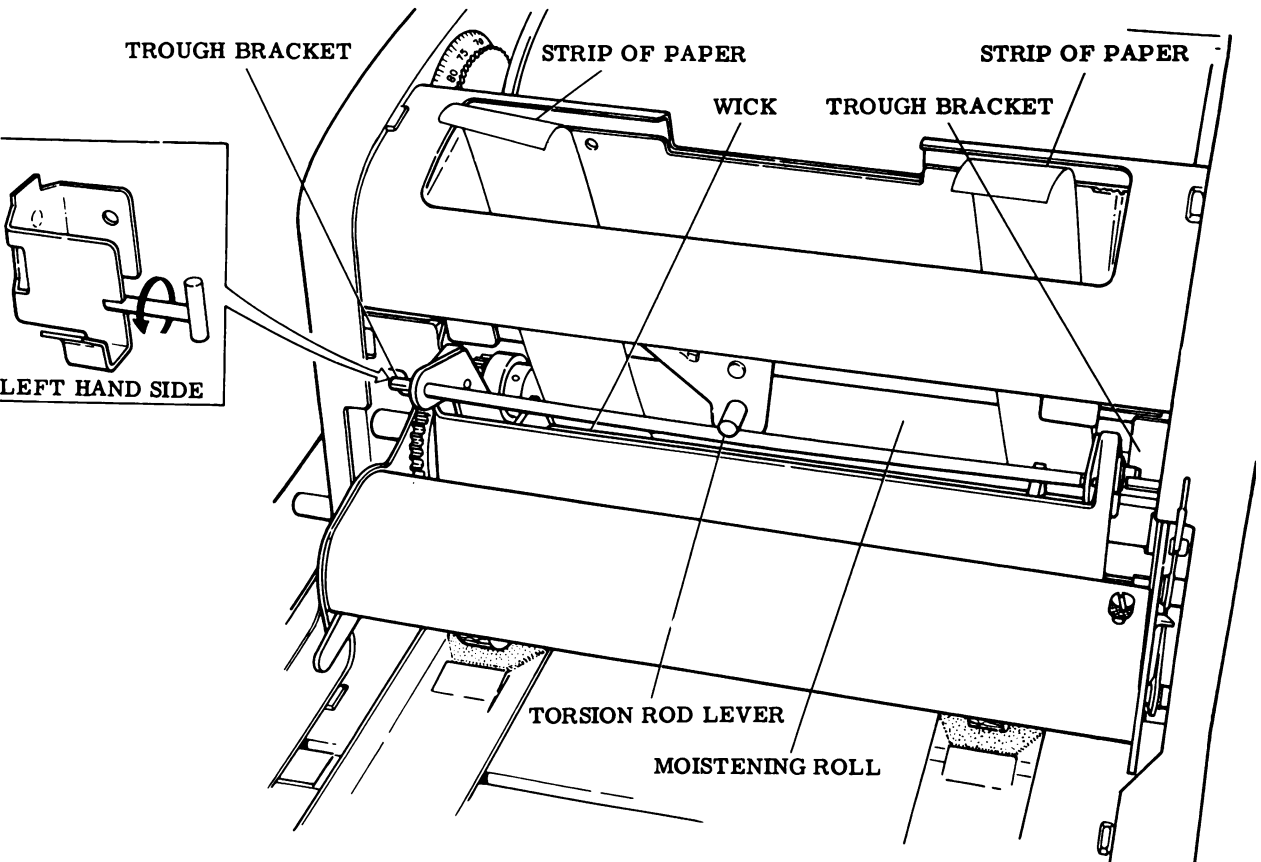


Figure 16-26.—Wick alignment.

91.90X

m here. If you have such machines in your p, use the appropriate manufacturer's man- to study the parts, functions, operation, and ntenance factors.

As far as the photo-copying process is con- ned, the Verofax machine requires special er and chemicals. The processing time for h machines is longer than for most dryelec- al processes.

Additional information concerning copying chines can be obtained from the manufac- er's operating manuals for machines in your p.

ADDRESSOGRAPHS

Addressographs are widely used throughout Navy for simplifying and speeding up routine ce work—addressing envelopes, and prepar- ay rolls, purchase lists, and inventories ply). These machines are useful for

reprinting the same information, of which a circular letter is a good example.

When embossed plates are put in an Ad- dressograph, the machine prints all the infor- mation on a single plate with one stroke (manu- ally or electrically operated). Information on these plates may be: names and addresses, service or payroll numbers, or other essential data.

Addressographs are grouped in classes in accordance with similarities of construction and operation. Machines within each group or class are designated as MODELS. Some of the different classes are:

1. CLASS 100, which holds only one address plate, inserted and removed manually before and after each printing.

2. CLASS 200, which is discussed in some detail in this chapter.

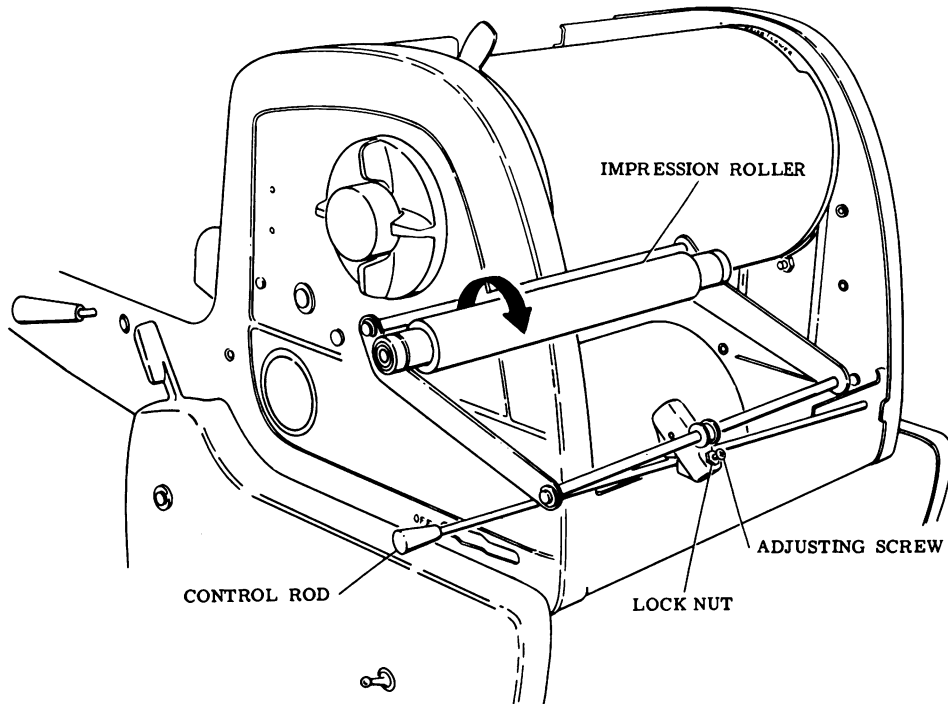


Figure 16-27.—Adjustment of impression roller pressure.

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3. **CLASS 500**, the simplest Addressograph, which holds only one plate at a time and is used primarily for proofing new plates as they come from the graphotype. (NOTE: Most graphotypes, discussed in IM 1 & C, NavPers 10194-B, are designed primarily for embossing metal plates used in Addressographs.)

4. **CLASS 700**, which is still in use by the Navy but which is being replaced by CLASS 200.

5. **CLASS 900**, which is discussed in some detail in Instrumentman 1 & C, NavPers 10194-B.

6. **CLASS 1900**, an improved type of Addressograph, discussed in some detail in Instrumentman 1 & C, NavPers 10194-B.

7. **CLASS 5000**, an Addressograph (with electronic controls), discussed briefly in Instrumentman 1 & C, NavPers 10194-B.

A Class 200 Addressograph is shown in figure 16-31. It is a hand-operated machine which is used rather extensively by the Navy. The embossed plates are placed in the magazine, face up, and with the index card toward the rear of the machine. Plates may be identified by the index card or by the tabs which are visible when

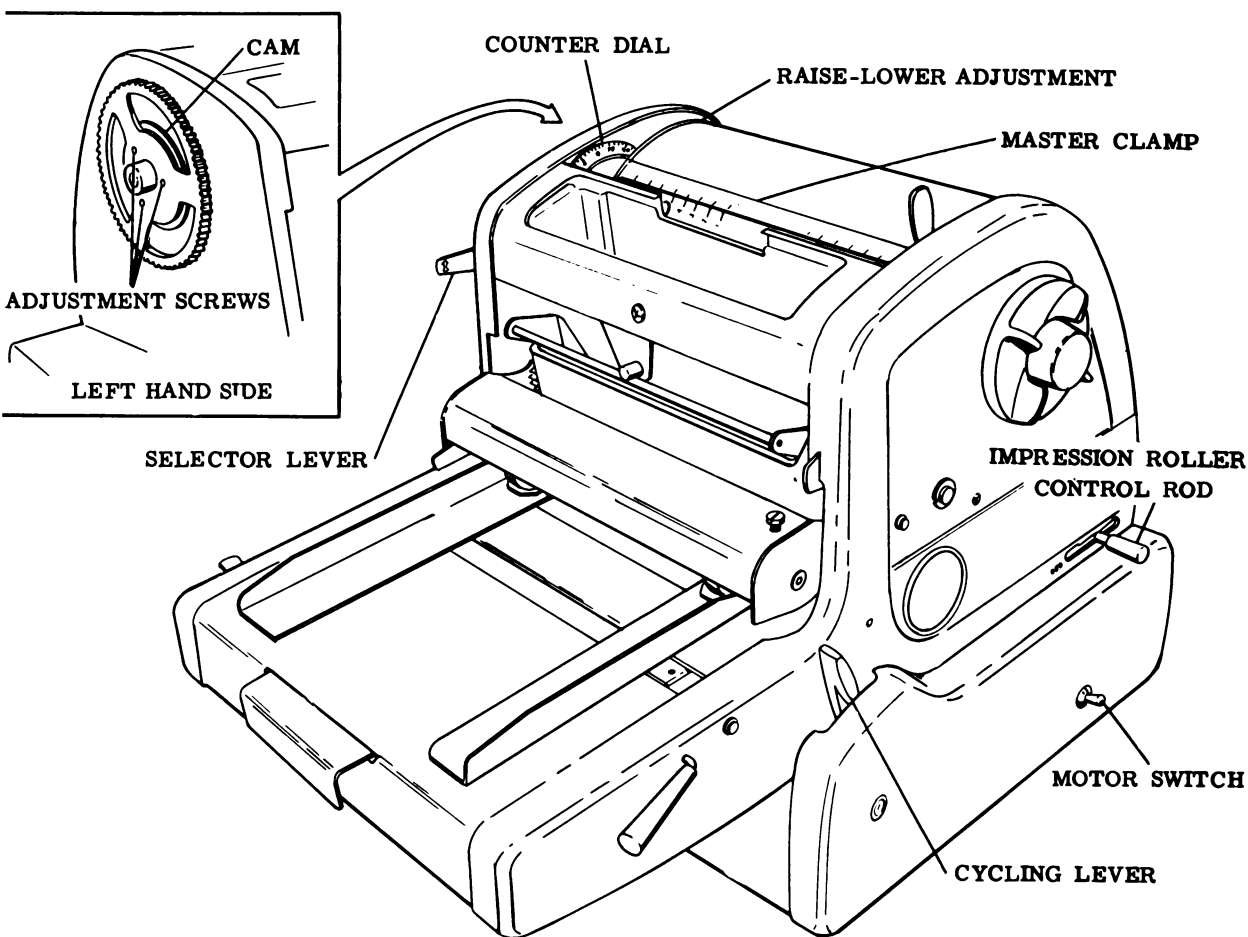
the plates are in printing position. Some of the parts and mechanisms of this Addressograph are explained next.

Skipper

The skipper (fig. 16-32) of the Class 200 machine is used TO ADVANCE the first plate from the magazine to printing position, and also to SKIP plates past the printing position (without making an impression). The operator of the machine can skip plates by pressing the skipper lever, as shown, and by bringing the platen head down against the bed of the machine.

Selector Lever

The selector lever (fig. 16-33) on the Class 200 machine operates the mechanism which enables the operator to make any number of impressions from one plate. When the selector lever is placed in the REPEAT position, for example, with the plate at PRINTING position, the plate remains in this position until the position of the lever is changed to the CONSECUTIVE spot.



91.92X

Figure 16-28.—Adjustment of clutch actuating cam.

Counter

A counter, shown in figure 16-33, visually registers the number of imprints made by an Addressograph from 1 to 99999. It does NOT register plates skipped through the machine, and the counter RESET knob is LOCKED when the platen head is in the UP position to prevent accidental resetting of the counter back to zero.

To reset the counter, move the platen head down against the bed of the machine and turn the reset knob COUNTERCLOCKWISE until the counter registers 99999. Then raise the platen head to the UP position to advance the counter wheels to zero.

Cut-Off

The function of a cut-off on an Addressograph is to prevent the printing of a portion of

the information embossed on a plate. Study figure 16-34 carefully. The cut-off consists of a platen with part of the rubber cut away, and a ribbon guard with the opening so cut that it covers the corresponding portion of the plate. Observe the curved dotted lines between the platen and the plate in figure 16-34.

The procedure for installing a cut-off on an Addressograph follows:

1. Press down on the platen handle (16-34) and then slide the standard platen off the left side of the platen head, as indicated by arrows in the illustration.

2. Install the cut-off platen by engaging the right end of the channel along the top of the platen over the left end of the track (on bottom of platen head).

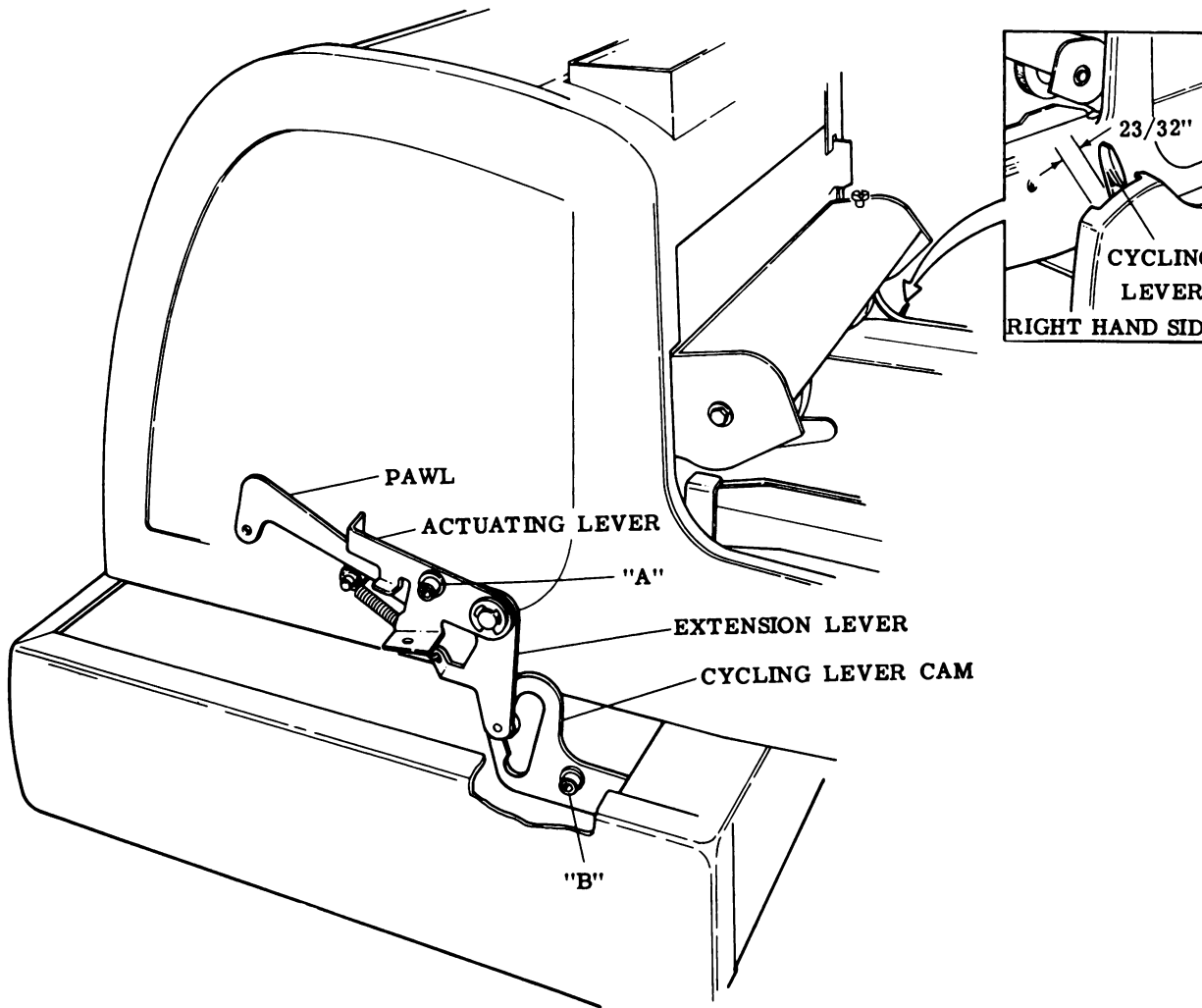


Figure 16-29.—Adjustment of cycling mechanism.

3. Remove the ribbon guard on the machine by lifting the left side of the guard enough for the retaining tab (illustrated) on the guard to clear the retaining hole in the machine and by sliding the guard to the left, off the machine.

4. Install the cut-off ribbon guard by inserting the edges of the guard in the rear and forward channels in the table top and then by sliding it to the right until the retaining tab on the guard snaps into the hole in the table top.

Daters

The function of daters on Addressographs is to print desired information to the right (right and left on double daters) of the address plate

impression, or within the printing area of the address plate. There are two types of register daters, RIGHT and OVERHEAD. A dater (right) is shown in figure 16-35. It is given this name because it prints information to the RIGHT of the address plate impression. An OVERHEAD dater (fig. 16-36) consists of an embossed dater plate secured to the ribbon support, as illustrated. The position of the dater plate coincides with a cut-out portion of the address plate and is held at the printing position.

Information concerning the installation of RIGHT and OVERHEAD daters can be obtained from either Instrumentman 1 & C, NavP 10194-B, or the manufacturer's technical manual for the specific unit(s).

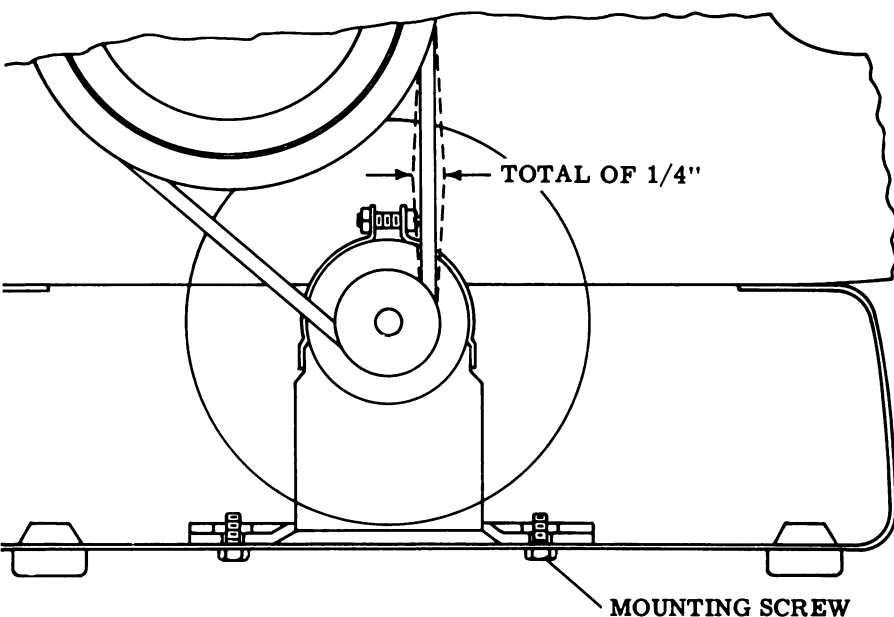


Figure 16-30.—Adjustment of the drive belt.

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own in figure 16-37, is used to list ruled or unruled paper. Spacing is adjustable, and one late impression may be listed. To list, push the feed roller con-

ter crank in the circle in figure 16-37 to increase or decrease spacing. Turn CLOCKWISE to increase spacing and COUNTERCLOCKWISE to decrease

is operated, it operates the ejector arm attached to the mechanism which operates the ejector foot. When the ejector foot snaps to the left, it ejects the envelopes or cards into a receiving hopper at the left of the machine. Attaching an ejector is a simple operation.

If the Addressograph has a lister, remove the cover plate and so locate the end of the ejector arm that the drive pin in the impression arm is through the hole in the bushing. Tighten the mounting screw. Then place an envelope or form on the machine in proper position for printing, loosen the lock nut and set the ejector foot to JUST TOUCH the right edge of the envelope, and line up the rear gage with the rear edge of the envelope.

ism
automatically ejects cards or forms from an Addressograph after they are printed. Study illustration 16-38, which shows the ejector mechanism on a machine, and the nomenclature. The ejector arm is secured by a bushing to the impression arm; and as the impression arm

Ribbon Mechanism

The ribbon cover mechanism for the Class 200 Addressograph is illustrated in figure 16-39. Note the position of the core retainer, locking tube in the retainer, the ribbon core driver, and the core retainer spring.

Table 16-1.—Lubrication Chart.

Name of Part	Lubrication Procedure
1. Cylinder drive gear	Grease the cam and brush grease into all gear teeth.
2. Upper and lower cam followers .	Grease the frame studs and oil the trucks and rivets.
3. Actuating lever	Grease the frame stud and the latch.
4. Release lever	Grease the frame stud and oil the truck and rivet.
5. Cycling lever	Grease both ends of the shaft and the cam surface.
6. Selector lever	Grease both frame screws and the extension.
7. Clutch pulley.	Grease the pulley shaft. CAUTION: Do NOT oil or grease the internal assembly of clutch 7A, or the brake facings of the actuating plate.
8. Counter	Grease the mounting screw, and brush grease into all teeth of the counter ratchet.
9. Counter lever	Grease the counter lever at the contact point with the raise-lower cam and at the lower end.
10. Feed roll shaft and gear	Grease both ends of the shaft, and brush grease into the gear teeth.
10A. Feed roll clutch.	Do NOT oil the teeth.
11. Large idler gear	Grease the mounting stud, and brush grease into the gear teeth.
11A. Small idler gear	Same as for large idler gear.
12. Feed roll cradle	Grease both cradle studs.
13. Gear segment	Grease the segment shaft, the gear teeth, and the cam slot. Oil the truck and rivet.
14. Moistening roller.	Grease both ends of the shaft.
14A. Moistening roller/clutch.	Apply a FILM of oil to the teeth of the clutch housing. Do NOT over oil the teeth.
15. Forwarding roll.	Grease both shaft bearings.
16. Cylinder shaft	Grease both shaft bearings.
17. Impression roller and pressure control rod	Grease the rod at both ends and at the center contact with the compression link.
18. Master loading lever	Grease the lever stud and oil the truck and rivet.
19. Master loading cam lever	Grease the cam surface and the stud.
20. Impression roller	Oil the shaft ends in the roller bearings.
21. Motor	Lubricate the bearings each month with 3 or 4 drops of S.A.E. #20 oil. If usage is heavy, oil more frequently.

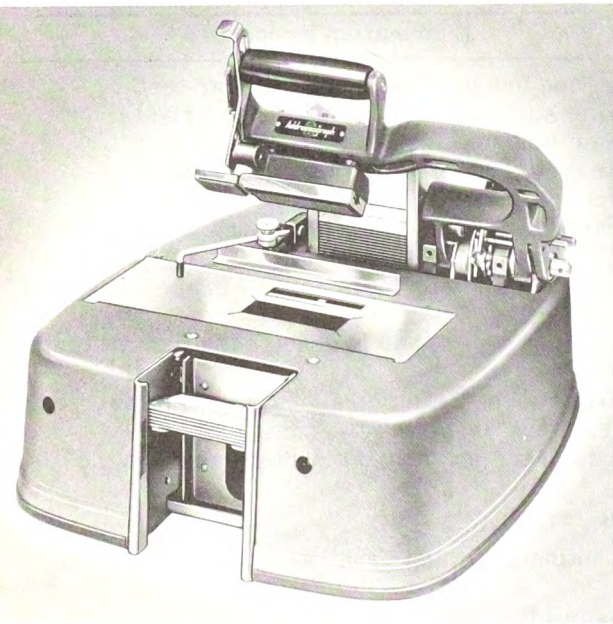
A properly inked ribbon is essential; otherwise, impressions are not distinct and even. If the impressions become too light, install a new ribbon in accordance with manufacturer's instructions.

Additional information concerning the adjustment, maintenance, and repair of Class 200 Addressographs, as well as other types of Addressographs, can be obtained from either Instrumentman 1 & C, NavPers 10194-B, or the

manufacturer's technical manual for the specific machine.

ADDING MACHINES

Because of the type of work they must perform, adding machines consist of many complicated mechanisms which must function in a precise manner for the machines to perform



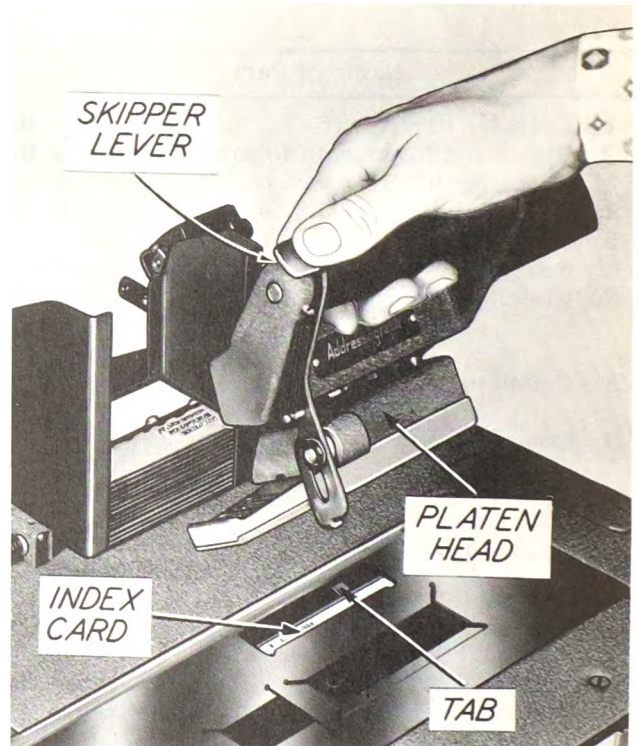
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Figure 16-31.—Class 200 Addressograph.

satisfactorily. Aboard ship, Instrumentmen have the responsibility for cleaning and adjusting adding machines, and they may also be required to maintain and repair them. The cleaning process for adding machines is essentially the same as for typewriters. All parts which are not damaged by recommended solvents and cleaning solutions can be left on the machine when it is submerged in cleaning solution, or put in a cleaning machine. Electrical and rubber parts are damaged by cleaning agents and must NOT be put in solutions used for cleaning metal parts. Clean rubber parts with a clean cloth and denatured alcohol.

As in IM3 or an IM2, however, you should know the nomenclature, function of parts of a typical machine, and definitions of terms associated with the repair of adding machines in the event that you may be required to assist in the maintenance of such machines.

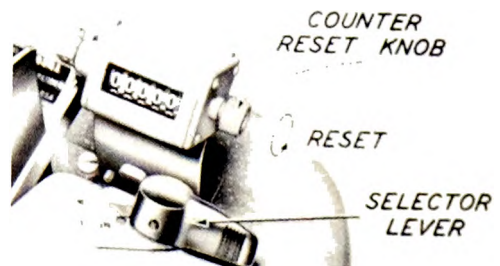
The Navy procures adding machines from various manufacturers, but space in this section permits discussion of only one make. Burroughs



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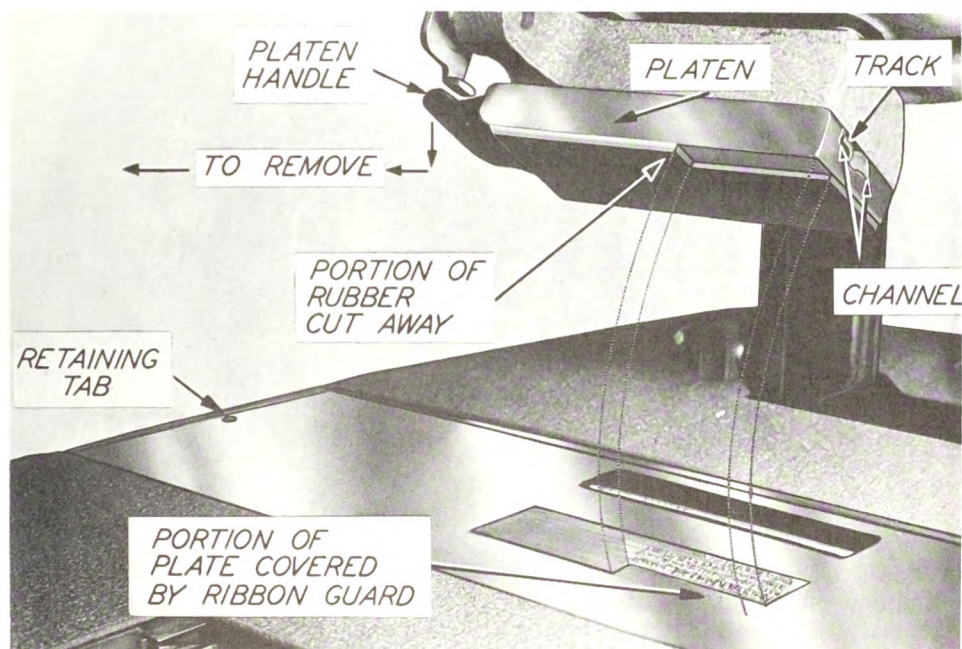
Figure 16-32.—Operating the skipper.

adding machines have been selected for consideration as a representative type because they are used extensively throughout the Navy, and some series may be used as cash registers on which an IM1 or an IMC may be required to perform maintenance.



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Figure 16-33.—The counter.

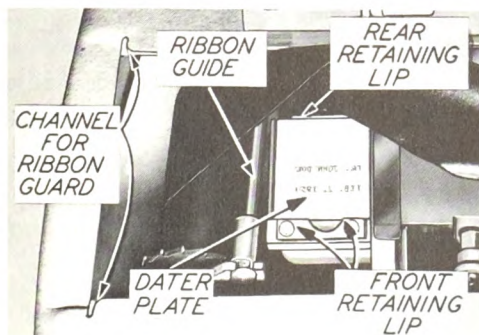


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Figure 16-34.—The cut-off.

BURROUGHS SERIES P ADDING MACHINES

Burroughs Series P adding machines, one of which is illustrated in figure 16-40, are manually and manually-electrically operated, and they are also used for cash registering and bookkeeping. The full keyboard has as many as thirteen columns of keys for listing figures or other information to be printed either on roll paper or bookkeeping forms.



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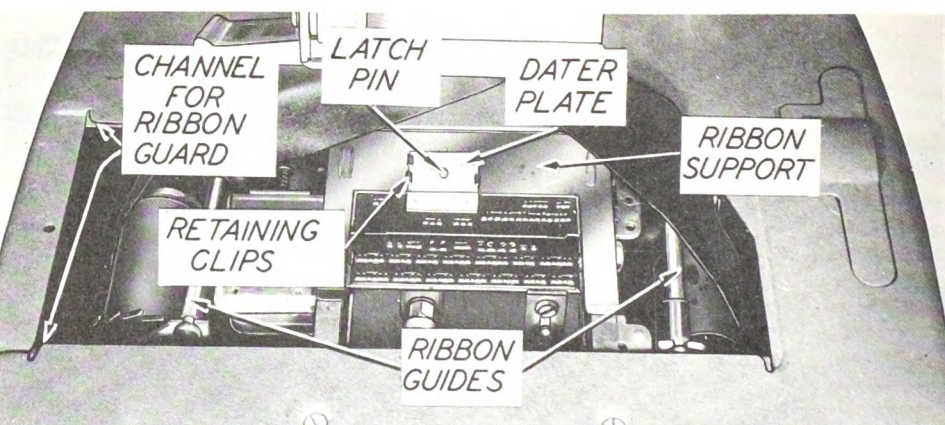
Figure 16-35.—Dater (right).

These machines are available with single or duplex registers—some for accumulating ADD items only and some for accumulating ADD and SUBTRACT items. A wide range of keyboard and accumulator mechanisms, plus many other basic and optional features, permits flexibility of use of these machines.

Series P100 adding machines are basic of the Series P line; other series have ADDITIONAL mechanisms designed to perform definite functions. Except for features applicable to certain series and/or styles, the number, construction and arrangement of registers in machines constitute the MAJOR differences in the various series.

Series P100 machines are operated manually or electrically and accumulate PLUS items only. Figures indexed on the keyboard print on a roll paper tape or form inserted in the carriage. Items may be repeated by depressing the REPEAT key, and they may be printed without accumulation by depressing the NON-ADD key. A total or subtotal can be obtained by depressing the TOTAL or SUBTOTAL key, respectively.

Uses of the Series P100 adding machine include: (1) accumulating figures on statements, deposit slips, and inventory slips; and (2) GENERAL PURPOSE cash registering, when

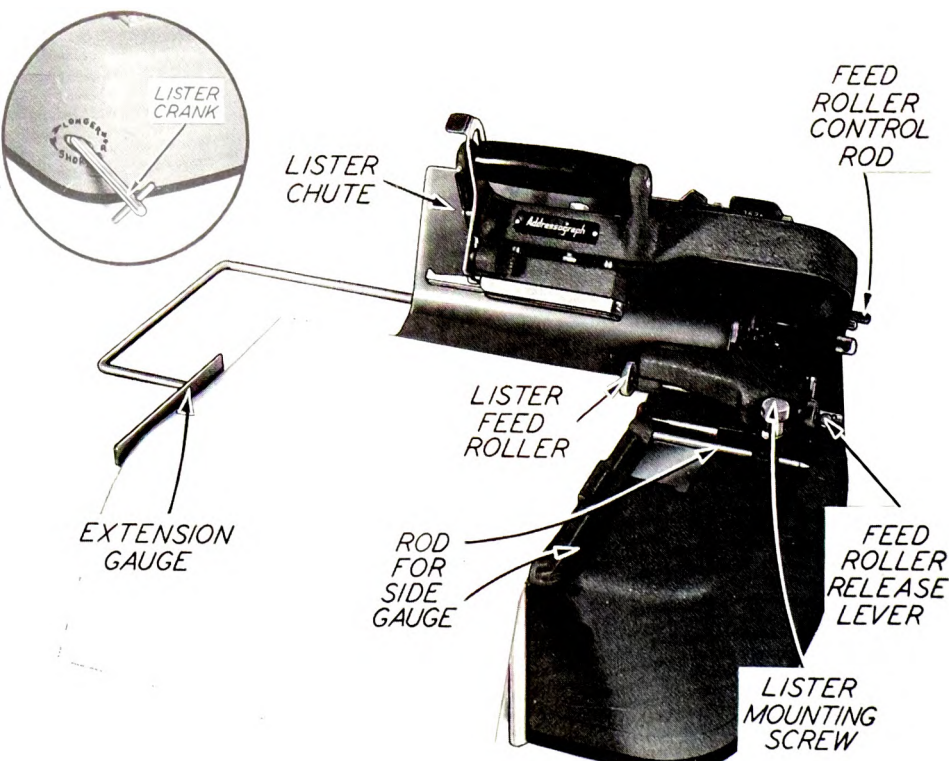


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Figure 16-36.—Dater (overhead).

in a paper rewind device and mounted
lower.
100 adding machines are also oper-
manually or electrically and they

accumulate both PLUS and MINUS accounts.
Repeat, non-add, and total action on this ma-
chine is identical with that of the Series P100
machine.



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Figure 16-37.—Lister.

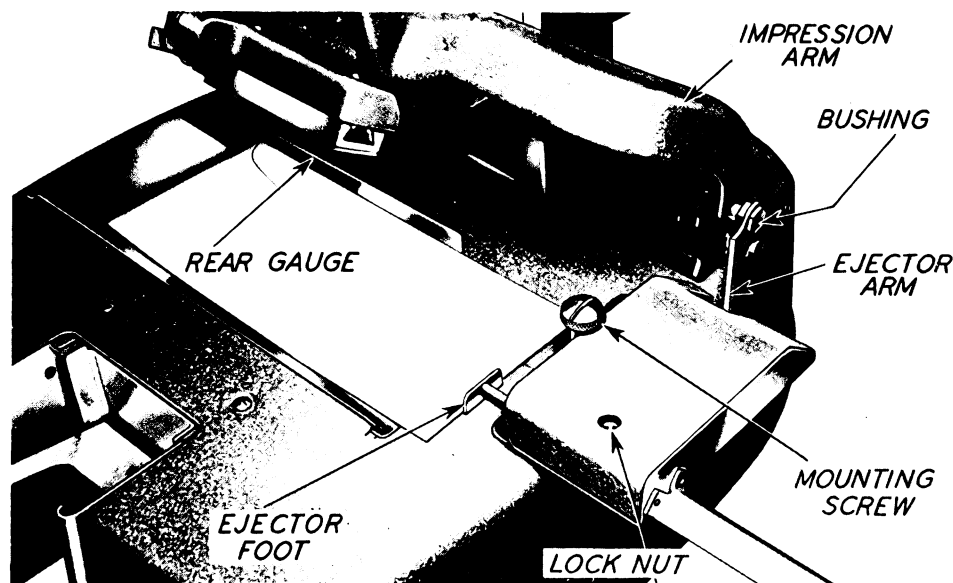


Figure 16-38.—Ejector mechanism.

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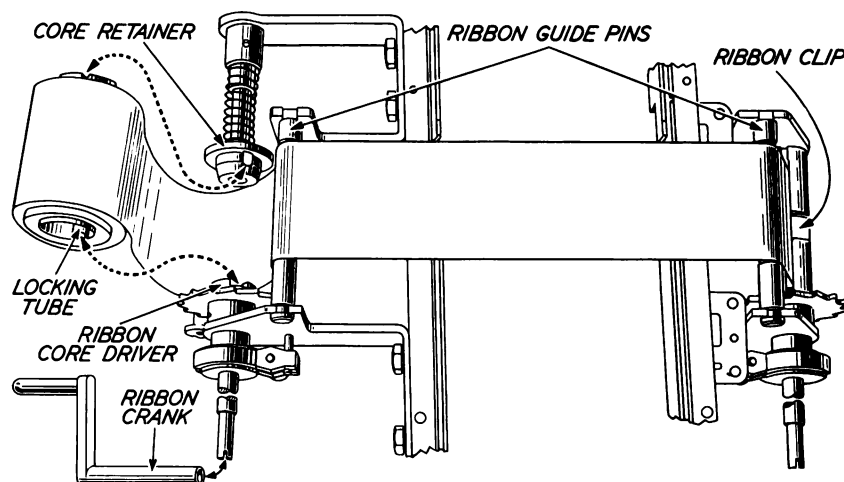
Series P300 Burroughs adding machines are operated electrically **ONLY**; otherwise, basically, they are similar to the Series P100 machines. The addition of a second independently controlled adding register to this machine, however, gives it a wide variety of applications in general office work involving multiple totals, and also for cash registering. When cash drawers are added to the Series P300 machine, by using the two totals, you can get the totals of individual sales during a specified period and also a gross total of sales at the end of the period. Amounts indexed on the keyboard may be added simultaneously in both registers by using the motor bar, or they may be added in either of the registers independently by using specified control keys.

The Series P400 adding machine has two registers and **ADDS** and **SUBTRACTS**. It accumulates one or two sets of figures, including both add and subtract items. When you put the register selection lever in the A or B position (designation of two registers), you get a single accumulation of figures. If you put the register selection lever (fig. 16-41) in the AB position, you get **SIMULTANEOUS** accumulation of **ADDED** or **SUBTRACTED** amounts. Plus or minus totals of these accumulations are printed on the tape and are identified by A or B and the proper total symbol.

When the number, date and normal lever (A) (fig. 16-41) is located in the extreme right position and the register selection normalizing key (latch down control key located below total key) is released, items accumulate alternately as the register selection lever automatically shifts back and forth. This feature enables the operator of the machine to list items such as quantity and value, old and new balances, debits and credits, and tax and amount.

If you place the date and normal lever in the center (split) position (with the register selection normalizing key latched down and the register selection lever in the AB position), you can list figures on both sides of the keyboard and add them simultaneously in both registers. This feature provides a means of converting the machine into a **FOUR-TOTAL** machine for obtaining **GROUP** totals and **GRAND** totals of listed amounts.

The Series P600 adding machine is a book-keeping machine used for posting accounts payable and accounts receivable. A line proof total and also a net proof total may be obtained in the accounts payable or accounts receivable applications. The line proof total (from register A) provides the difference between the old and new balance of an account. This should be the same as the net total of the charges and credits posted to the account during one posting operation. The



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Figure 16-39.—Ribbon mechanism.

net proof total (from register B) provides a net total of all the charges from credits posted during the complete posting run. This should be the same as the net total of the pre-list of all the items posted.

A red ribbon lift mechanism on this machine enables the operator to print selected information in RED. The feed carriage (15" length) can be opened and closed manually for easy insertion of forms from the front. The carriage also has a form aligning table, adjustable form guide, and a plastic journal holder.

MECHANISMS

The adding machine mechanisms discussed in this section are for the Burroughs Series P400 machine. This machine was selected because it has two registers, adds and subtracts, and is used by the Navy for many purposes. Information concerning adjustments can be obtained from either Instrumentman 1 & C, NavPers 10194-B, or the manufacturer's technical manual for the mechanism of a specific machine.

Form Spacing Mechanism

The form spacing mechanism for the Series P400 machine is illustrated in figure 16-42. It permits the selection of 5/6" spacing (jump totals) during total operations, so that figures will advance beyond the cutting edge of the tear-off blade in narrow carriages.

When the jump total spacing lever (disabling) is in the rear position, depression of the TOTAL key moves the slide to the limit bail (actuated by the total and subtotal keys) rearward and the slide to the limit bail (actuated by the total Key) forward to remove them from the path of the limit bail.

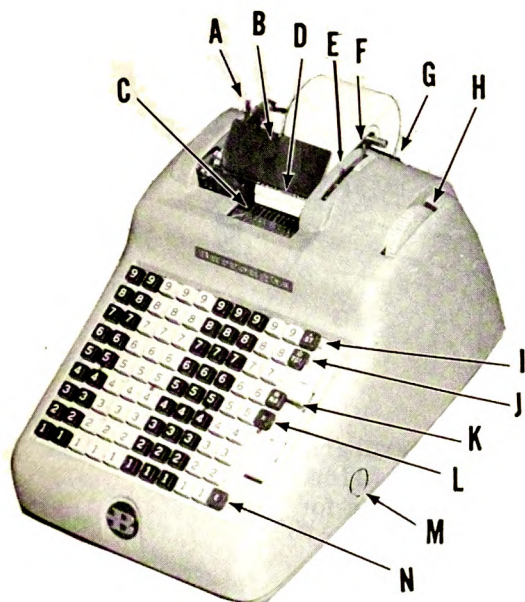
During the forward stroke of a total operation, the limit bail actuating arm moves out of the path of a stud on the limit bail to allow spring tension to rock the limit bail. Rocking of this bail through the space control link, the space control arm, and a bellcrank permits the paper feed pawl to engage the platen ratchet gear to space the form 5/6 inch.

When the disabling lever is positioned to permit 5/6" spacing during total operations, the two slides to the limit bail restrict action of the bail to prevent 5/6" spacing during listing operations—the slide which is actuated by the total and subtotal keys prevents 5/6" spacing during listing operations, and the slide which is actuated by the total key prevents 5/6" spacing during subtotal operations.

If the disabling lever is in its forward position, spacing during total operations is the same as that indicated by the adjustable form space control.

Error Key Mechanism

Study the error key mechanism illustrated in figure 16-43. This mechanism enables the operator to release incorrectly indexed listing



- | | |
|----------------------------------|--|
| A. Pressure roll release lever | G. Roll paper shaft |
| B. Writing table | H. Platen twirler |
| C. Platen | I. Subtotal key |
| D. Transparent tear-off blade | J. Total key |
| E. Jump total spacing lever | K. Non-add key |
| F. Adjustable form spacing lever | L. Repeat key |
| | M. Swing-away shutter for handle insertion |
| | N. Error key |

91.139X

Figure 16-40.—Series P full keyboard adding machine.

keys, operating keys, and motor bars before the machine is operated.

When the error key is depressed, it lowers the error arm and rocks the key release bail, which (by means of projections on its upper portion) moves the locking strip rearward to clear the key stems. The released keys are then returned to their rest positions by the key restorer springs. Rocking of the key release bail also swings the locking strip rocker arm, which (through its lowest stud's contact with the lip on the foremost part of the latching arm for plus and minus bars) moves the latches on the latching arm for plus and minus bars clear of the steps on the motor bars. Restoration of the motor bars is then provided by spring tension.



- | | |
|--------------------------|----------------------------|
| A. Date and normal lever | E. Repeat key |
| B. Subtotal key | F. Register selector lever |
| C. Total key | G. Error key |
| D. Non-add key | |

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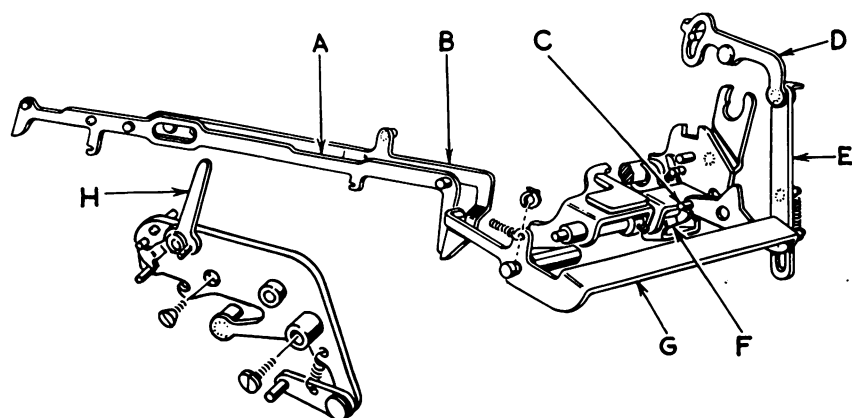
Figure 16-41.—Series P400 adding machine.

Repeat Key Interlock

When the register selector control lever (F), fig. 16-44 is unlatched, the register selector lever automatically alternates from the A to the B position, and vice versa, on each machine operation and depression of the repeat key is blocked. Stud E (fig. 16-44) is now positioned over the back part of arm D, preventing it from rocking, and also from blocking the depression of the repeat key.

If the register selector lever control key (F) is latched down when you depress the repeat key, the action lowers the repeat arm, which (through the stud on arm D) positions the rear portion of arm D in the path of the stud (E) that limits on arm D to prevent release of the control key.

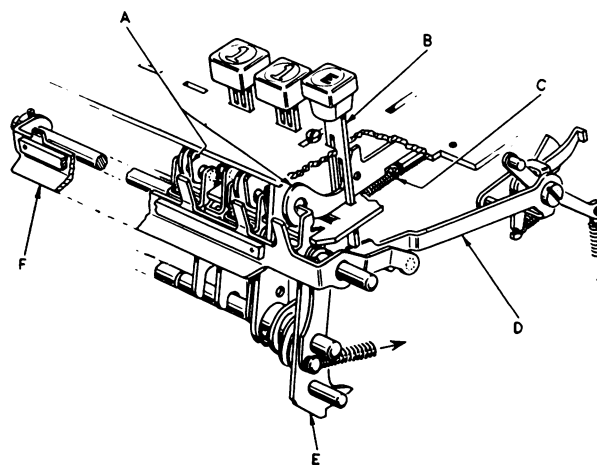
To prevent the printing of symbols, depress the repeat key. When you do this, arm D rocks and lowers lip C (fig. 16-44) to allow the hooked portion of latch I to move over lip C as roller H moves rearward during the forward stroke. Latch I then holds lip G in the path of the



- | | |
|--|-----------------------------|
| A. Slide to limit bail G (actuated by total key) | D. Space control arm |
| B. Slide to limit bail G (actuated by total and subtotal keys) | E. Space control link |
| C. Stud on bail G | F. Actuating arm for bail G |
| | G. Bail |
| | H. Jump total spacing lever |

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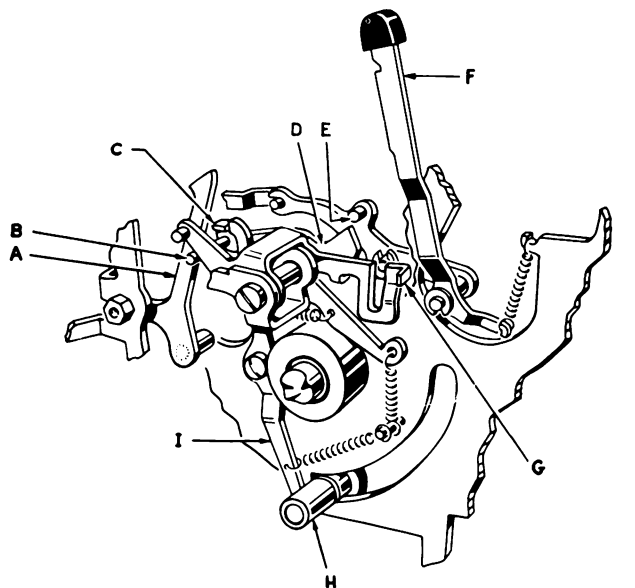
Figure 16-42.—Form spacing mechanism.



- | | |
|-----------------------------|---|
| A. Locking strip | E. Rocker arm controlling locking strip in column 0 |
| B. Error key stem | |
| C. Key stem restorer spring | F. Bail which releases keys from error key |
| D. Error arm | |

91.142X

Figure 16-43.—Error key mechanism.



- | | |
|---|---|
| A. Repeat arm | F. Register selector control lever |
| B. Stud on arm D | G. Lip which blocks forward movement of index bar in column O |
| C. Lip on arm D which is engaged by latch I | H. Roller on secondary mechanism |
| D. Arm which blocks travel of stud E | I. Latch which holds arm D in the raised position |
| E. Stud which limits on arm D | |

91.143X

Figure 16-44.—Repeat key interlock.

projection on the underside of the index bar in column O in case the repeat key is released before the operation is completed during repeat operation of added items.

Near the end of the return stroke, the forward movement of a roll (H) on the secondary mechanism rocks the latch which holds arm D in the raised position out of engagement with the lip on arm D to allow lip G to move down and out of the path of the underside of the index bar in column O.

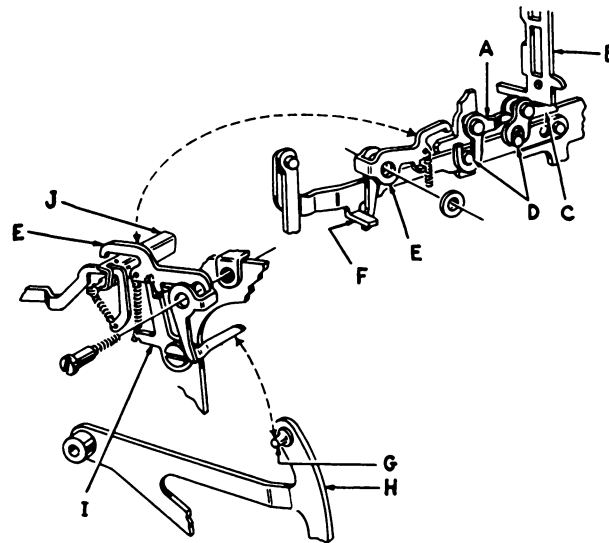
When the TOTAL keys of the Series P400 adding machine are held depressed, repeat total operations are blocked. A handle break also occurs then to prevent complementary totals. This safeguard is necessary when the register selector lever automatically shifts to or from

a register with a minus amount when the other register has a plus amount.

As the total keys are depressed (B, fig. 16-45), bellcrank A or C, which actuates the slide (F) that controls the interlock (E) (blocks movement of the channel bail), moves the slide to the rear to allow interlock E to be pulled down into engagement with latch I.

During a forward stroke of the machine as segment arm H moves upward, stud G releases latch I from interlock E and permits interlock E to be pulled down into engagement with the channel bail.

If the total keys are held depressed manually during a machine operation, the slide which controls the interlock remains to the rear and the interlock (E) remains engaged with the channel bail to cause a handle break.



- | | |
|-------------------------------------|--|
| A. Bellcrank which actuates slide F | E. Interlock which blocks movement of channel bail J |
| B. Subtotal key stem | F. Slide which controls interlock E |
| C. Bellcrank which actuates slide F | G. Stud on segment arm H |
| D. Stud on slide F | H. Segment arm |
| | I. Latch which limits interlock E |
| | J. Channel bail |

91.144X

Figure 16-45.—Blocking of repeat total operations.

Motor Bar and Control Key Interlocks

Simultaneous depression of operation control keys and/or motor bars is prevented by interlocks which stop machine lockup and wrong addition. Study figure 16-46 as you follow the discussion of these interlocks.

When a total key is depressed, it causes bellcrank K to rock and to move slide M rearward. Slide M then rocks link N and moves interlock P forward to locate its formed ears under minus bar B and plus bar E to block depression.

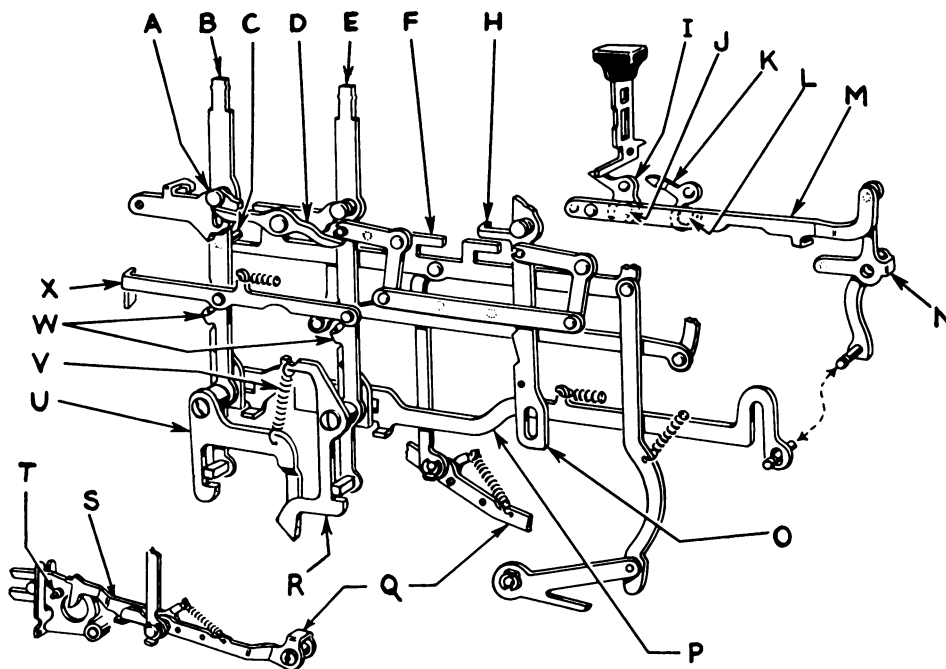
Depression of the minus bar (B) or the plus bar (E) positions the formed ear on the lowest part of the depressed motor bar into the path of the interlock, thereby preventing forward movement of the interlock.

Operation of the machine, and a subsequent lock by partial depression of the non-add key, is

prevented by the interlock (S) which limits rearward movement of the stud on the key restoring arm.

Another interlock (U) prevents a snap depression of the minus motor bar during the last part of a plus operation to prevent the minus wheels from being partially shifted while a relay carry takes place. If allowed, partial shifting could cause the wheels to be moved out of alignment with the carry racks and perhaps cause either a loss of carry or a lockup.

Interlock R (fig. 16-46) prevents a snap depression of the plus bar during the last part of a minus operation. If it were possible to snap the plus bar when a minus carry originating in column 6 or 7 is taking place, a loss of carry or a lockup could result, as follows: A plus operation could start, causing the wheels to be moved out of alignment with the carry racks before the carry could be completed to column



- | | |
|---|--|
| <p>A. Stud on minus bar which actuates interlock D</p> <p>B. Minus motor bar</p> <p>C. Stud (on minus bar) which lowers the intermediate bar (F)</p> <p>D. Interlock which prevents simultaneous depression of plus and minus motor bars</p> <p>E. Plus motor bar assembly</p> <p>F. Intermediate motor bar</p> <p>H. Lip (on motor bar assembly) which actuates intermediate bar F</p> <p>I. Bellcrank which actuates slide M</p> <p>J. Stud on slide M</p> <p>K. Bellcrank which actuates slide M</p> <p>L. Stud on slide M</p> <p>M. Slide which actuates link N</p> <p>N. Link connecting slide M and interlock P</p> | <p>O. Rear plus bar</p> <p>P. Interlock which prevents depression of motor bars when total keys are depressed</p> <p>Q. Arm which actuates interlock S</p> <p>R. Interlock which prevents snap depression of the plus bar during minus operations</p> <p>S. Interlock which limits rearward movement of stud T</p> <p>T. Stud on key restoring arm</p> <p>U. Interlock which prevents snap depression of minus bar during plus operations</p> <p>V. Spring which actuates interlocks R and U</p> <p>W. Lips on latching arm X</p> <p>X. Latching arm for plus and minus bars</p> |
|---|--|

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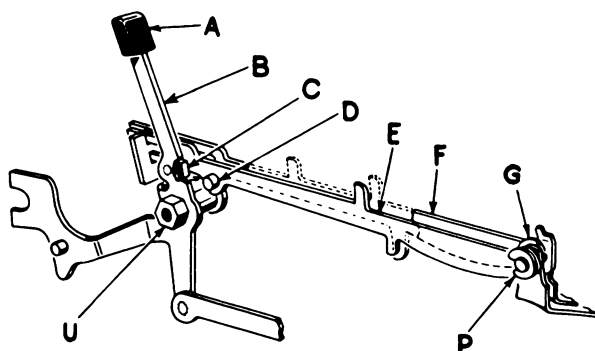
Figure 16-46.—Motor bar and control key interlocks.

13, then back to column 1 through the automatic carry one bail and over to the column in which the carry originated.

Symbol Indexing Mechanisms

Various functions of registers A and B are identified by symbols printed to the right of printed amounts. Symbol type is positioned in columns 0 and 00 on adding racks controlled by symbol index bars F and E, respectively. Positioning of the index bars is controlled by the operation control keys, register selector lever, or a motor bar.

Symbol printing in column 00 is controlled by the position of lever B (fig. 16-47). The three positions of register selector lever B determine the location of stud C which, in turn, acts as a limit for the forward travel of index bar E (column 00) through stud D.



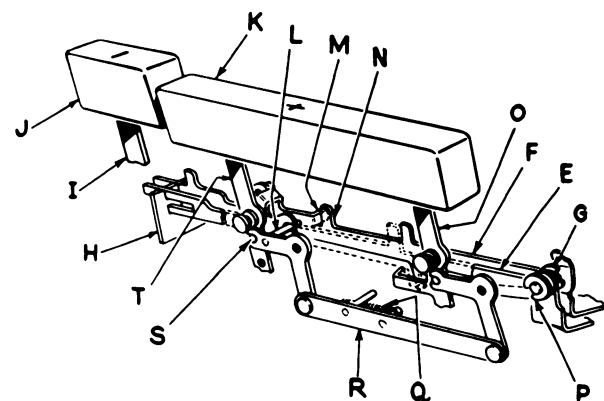
91.146X

Figure 16-47.—Register A and/or B accumulation.

The index bar in column 0 is blocked by depression of the plus motor bar K (fig. 16-48). When this bar is depressed, it causes a lowering of lip M into the path of projection N, link R, and stud L. The lowering of lip M into the path of projection N prevents the index bar (F) for column 0 from moving forward, thereby allowing printing of the register indexing symbol ONLY.

If the minus motor bar (J, fig. 16-49) is depressed, it causes a lowering of lip AJ into the path of projection AG, permitting index bar F for column 0 to move to a designated position for printing the minus symbol.

When the repeat key (W, fig. 16-50) lowers arm AF, the arm then raises lip Z into the path of projection Y to block forward movement of the index bar for column 0.

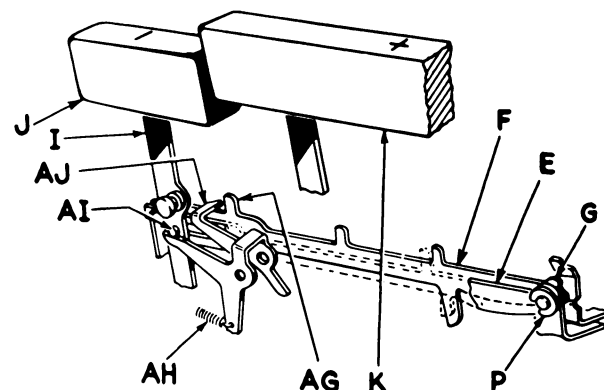


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Figure 16-48.—Symbol index blocking by plus motor bar.

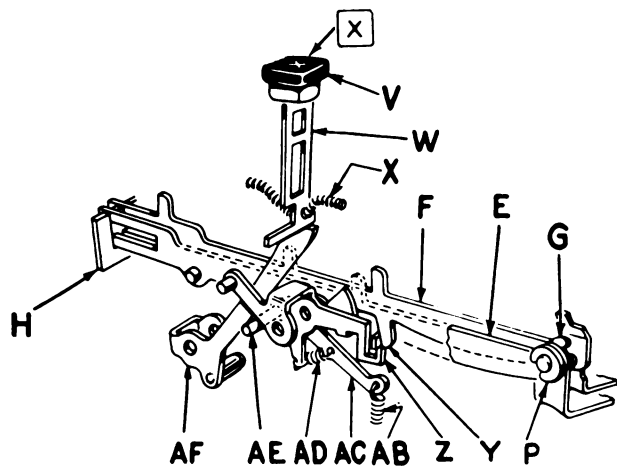
Simultaneous depression of the minus motor bar (J, fig. 16-51) and the repeat key stem (W) lowers lip AJ into the path of projection AG. At the same time, the rear tail of part AJ lowers lip Z out of the path of projection Y, permitting the positioning of index bar F (column 0) for printing the minus symbol.

The NON-ADD key limits the index bar in column 0 for printing and blocks the index bar in column 00. Study figure 16-52. If the non-add key stem (AK) is depressed, it blocks the forward movement of the index bar (E for column 00) at point AM. During the forward stroke of an operation, index bar F for column 0 moves forward until projection AL limits against the rear part of key AK to print a specified symbol.



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Figure 16-49.—Minus symbol indexing (column 0).

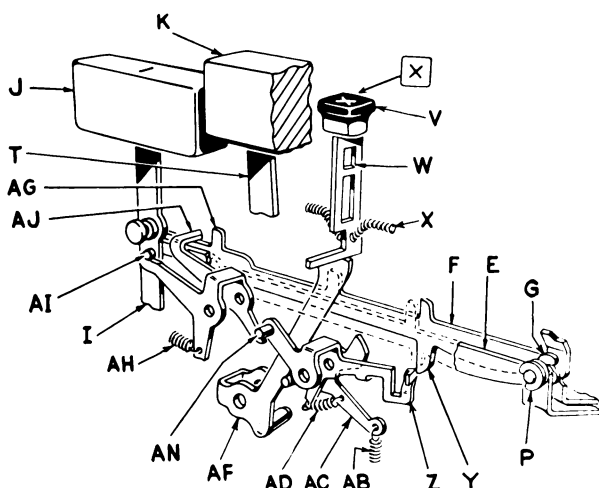


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Figure 16-50.—Prevention of symbol printing in column 0.

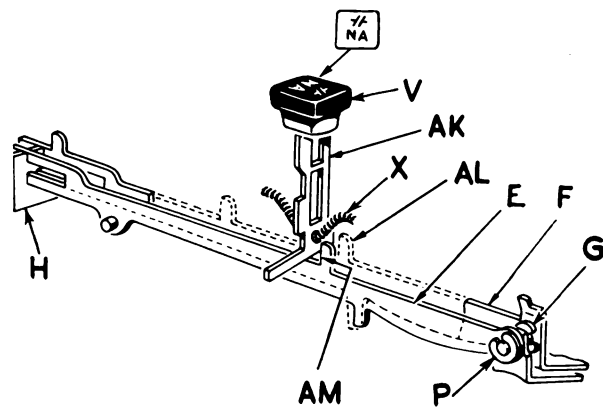
When the total key stem (AO, fig. 16-53) is depressed, it positions the lowest part of the key in the path of projection AP, allowing the index bar for column 0 to travel forward until it is limited by the depressed key for printing a specified symbol.

Depression of the subtotal key stem (AO, fig. 16-54) places the lowest part of the key behind projection AP, permitting index bar F to travel forward until point AQ is stopped by guide H for printing a specified symbol.



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Figure 16-51.—Symbol printing in column 0.

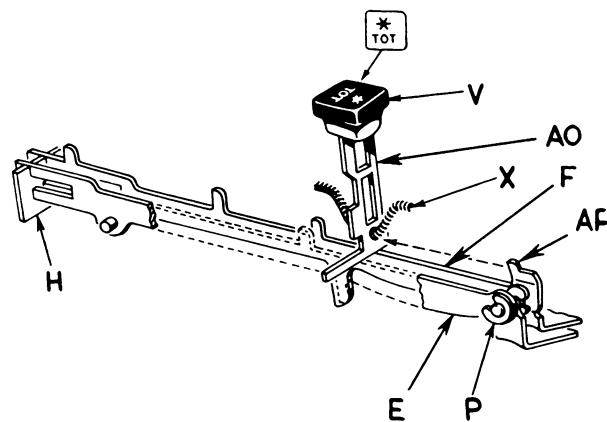


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Figure 16-52.—Action of non-add key on index bars in columns 0 and 00.

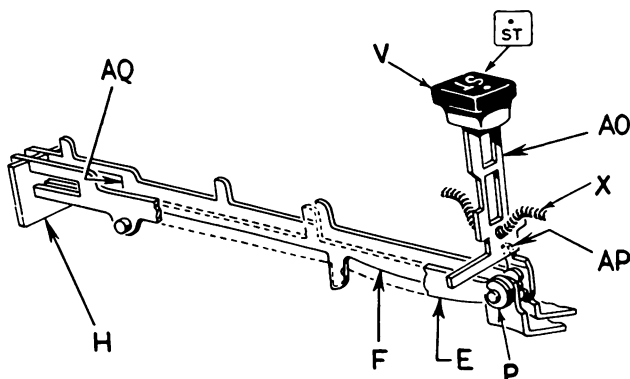
When a minus balance is indexed, slide AT (fig. 16-55) is positioned forward to locate its upright projection under the total key stem (AO). Depression of key stem AO lowers the forward portion of slide AT, which (in turn) lowers slide AV to position lip AR in the path of projection AP. During a forward stroke, travel of index bar F for printing a specified symbol is limited by lip AR's limiting against the rear portion of key stem AO.

In the minus balance position, slide AT (fig. 16-56) is positioned forward, locating its upright projection under key stem AO. If key AO is depressed, the action causes a lowering of the front part of slide AT which then lowers slide

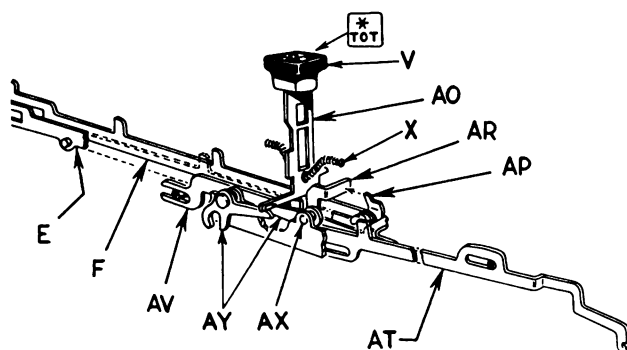


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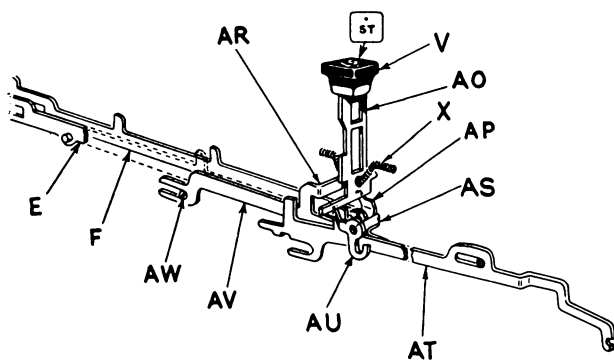
Figure 16-53.—Limitation of index bar in column 0 by the total key.



91.153X
Figure 16-54.—Limitation of index bar in column 0 by guide H.



91.154X
Figure 16-55.—Limitation of forward travel of index bar in column 0 by lip on slide AV.

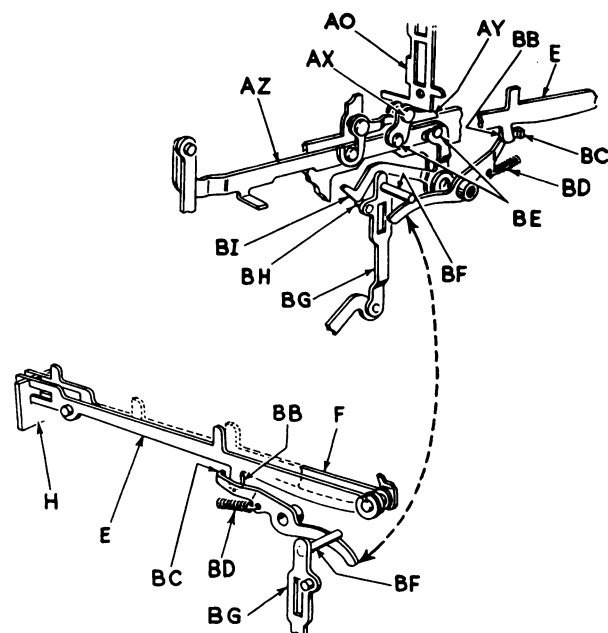


91.155X
Figure 16-56.—Control of travel of index bar in column 0 by slide AV.

AV to place lip AR in front of key stem AO and in the path of projection AP.

During the forward stroke of an operation, travel of index bar F for printing a specified symbol is limited by slide AV's limiting against stud AW.

Depression of the TOTAL key stem (AO, fig. 16-57) rocks bellcrank AY, which moves slide AZ rearward to rock arm BI down. As arm BI moves downward, it contacts stud BH to lower link BG. Then link BG raises lip BC into the path of projection BB to limit travel of index bar E for column 00 for printing symbol "A".

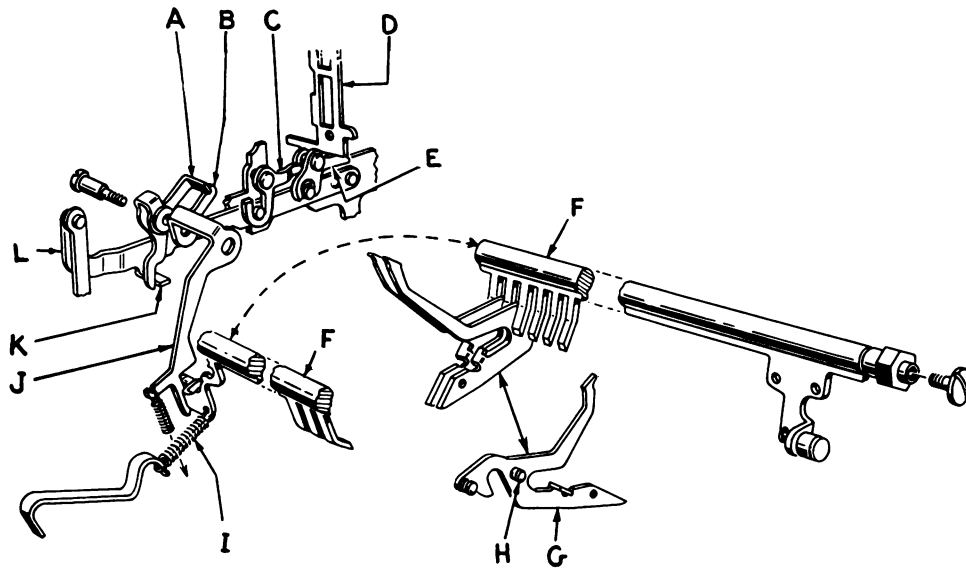


91.156X
Figure 16-57.—Printing of symbol A during plus and minus totals with register selection lever at AB.

Total Keys Index Hammer Block Mechanism

Printing in specified columns is controlled by the total keys to prevent the printing of folio numbers with totals when the number, split and normal lever is in the number position (extreme left).

When a total or subtotal key stem is depressed, the action rocks bellcrank C or E (fig. 16-58) which moves slide D rearward, causing bellcrank A to rock through lip K. Bellcrank A



- | | |
|--|---|
| A. Bellcrank which actuates bail J | H. Roll on hammer latch |
| B. Finger of bail J. | I. Spring which actuates bail F |
| C. Bellcrank which actuates slide L | J. Bail which holds bail F in normal position |
| D. Total key stem. | K. Lip on slide L |
| E. Bellcrank which actuates slide L | L. Slide which actuates bellcrank A |
| F. Bail which indexes hammer latches (G) | |
| G. Hammer latch | |

91.157X

Figure 16-58.—Total keys index hammer block mechanism.

then rocks finger B downward to raise the rear portion of bail J, allowing the actuating bail spring (I) to rock the indexing hammer latch bail (F). The fingers of bail F are therefore rocked into the paths of rolls on the hammer latches (G and H), thereby preventing the latches from contacting the hammers as the racks move up.

Intermediate Indexing Mechanism

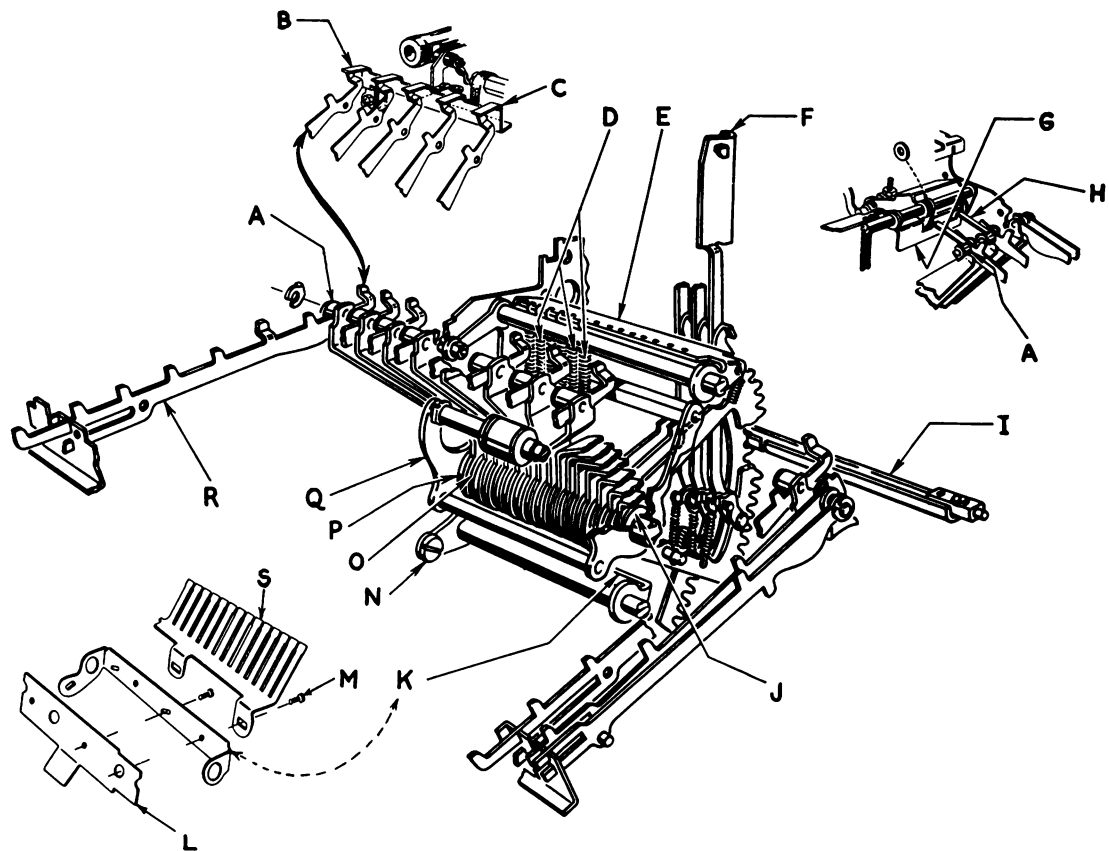
The intermediate indexing mechanism positions type bars in a position to correspond to keys indexed on the keyboard. The adding racks, assembled within frame Q with collars J, O, and P (fig. 16-59) carry type bars F and are controlled by movement of the indexbars (R), which are limited by their upright projections stopped by key stems 1 through 8. When the No. 9 key is depressed, the racks move upward and are limited in movement by the limit bail for adding racks in the No. 9 position. When no keys are

depressed, forward movement of the index bars is prevented at cipher position by the foot of the cipher stops.

The sector limit plate (L) limits downward movement of the adding racks to prevent their overthrow, which could result in: (1) a point-to-point lock of the adding pinions and the adding racks during a handle break with the total key depressed; and (2) over addition, caused by tripping off carries when adding figure 9.

In addition to the slots provided in the aligning shaft, guides I and S guide the adding racks to maintain their alignment with the adding pinions.

There are two braces which prevent excessive upward movement of the adding racks in columns 1, 2, and 8 through 13 during machine operations in which these adding racks are active. See C and G in figure 16-59. Excessive upward movement of these adding racks may prevent full engagement of the aligning shaft with the adding racks, causing uneven printing.



- | | |
|---|---|
| A. Index bar (R) retaining clip | K. Bail which retains guide S and limits plate L |
| B. Finger on brace C | L. Plate which limits downward movement of adding racks |
| C. Brace which prevents excessive upward movement of adding racks | M. Screw which secures guide S |
| D. Adding rack springs | N. Screw which holds bail K to the left side frame |
| E. Limit bail for adding racks in the No. 9 position | O. Space collar |
| F. Type bar | P. Space collar |
| G. Brace which prevents excessive upward movement of adding racks | Q. Restoring frame |
| H. Finger on brace G | R. Index bar |
| I. Guide for adding racks | S. Guide for adding racks |
| J. Space collar | |

Figure 16-59.—Intermediate indexing mechanism.

91.158X

Register Selector Mechanism

The register selector mechanism for the Series P400 Burroughs adding machine is shown in figure 16-60.

Automatic alternating selection of register A or register B (when the register selector lever control key in position 7-0 is released) permits accumulation in alternate registers while you are listing consecutively. This feature provides a means by which items such as old and new balances, debits and credits, and amounts may be listed during the same run.

During the early part of the forward stroke of a machine operation, with the register selector control key in the released position, as arm M moves away from roller N, arm E and spring C pull link J down. Downward movement of link J positions the roll on arm D against the lowest part of the spear point of pawl A and, at the same time, limits stud L on the step of latch K to safeguard against automatic shifting of the register selector lever (H), if a handle break occurs.

As the forward stroke continues, the front part of the dashpot actuating arm assembly rocks latch K away from stud L to allow link J to move farther down and the roller on arm D to be indexed on the opposite side of the spear point of pawl A.

Near the end of the return stroke, arm M engages roll N, which moves the roller on arm D into engagement with pawl A to reverse the position of lever H through stud I.

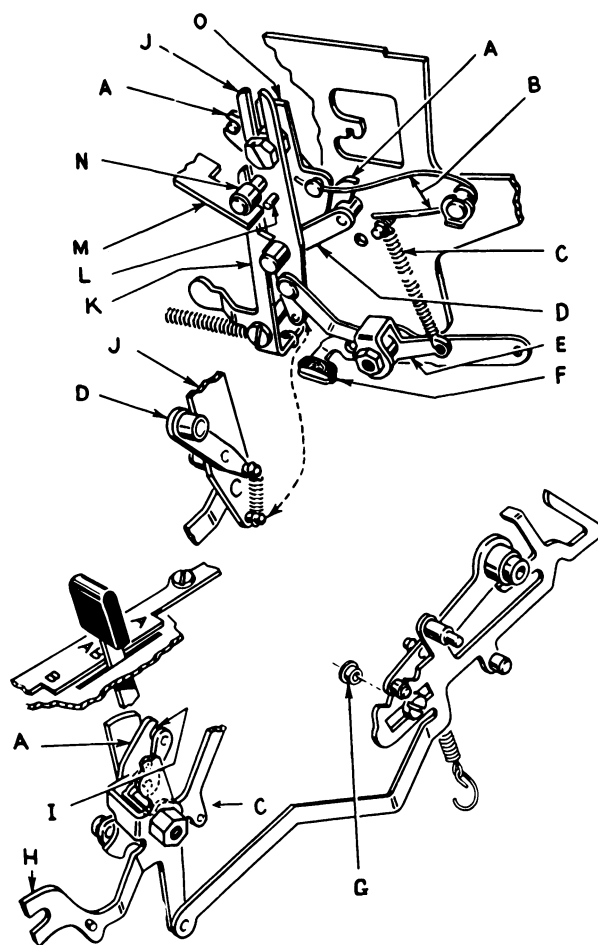
When the register selector control key (AA, fig. 16-61) is depressed, it prevents automatic shifting of the register selector lever, thereby permitting the operator to select registers when listing PLUS and MINUS amounts.

Depression of the control key lowers the slide (O) which prevents automatic shifting of the register selector lever. The lowering of slide O moves roller AD out of the pocket in pawl A to permit manual shifting of the register selector lever.

During the forward stroke of a machine operation (with key AA latched depressed as link J moves downward), roller AD is carried down the incline of slide O just short of the spear point of slide O, thus leaving arm D in an inactive position.

Register Selector Lever Interlock

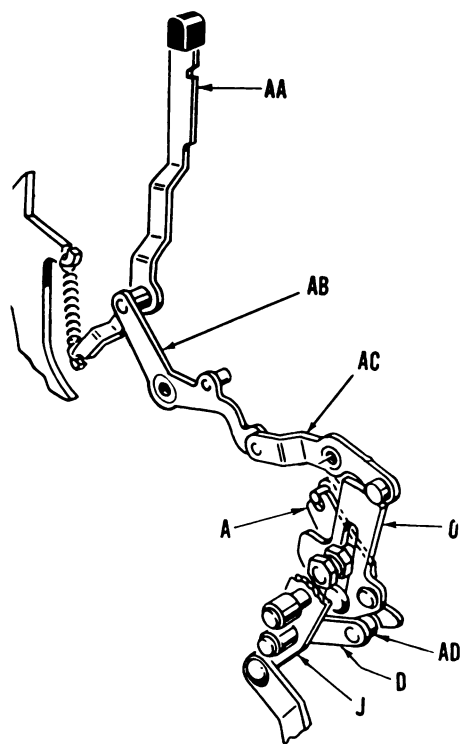
The register selector lever interlock blocks movement of the lever when the total keys are depressed. Study figure 16-62.



- | | |
|--|---|
| A. Pawl which reverses the position of the register selector lever | I. Stud which connects the register selector to pawl A |
| B. Spring which restores slide O | J. Link which arm E actuates |
| C. Spring which pulls arm E | K. Latch which prevents shifting of lever H during handle breaks |
| D. Actuating pawl (A) arm | L. Limit stud for link J |
| E. Arm which pulls link J | M. Arm which restores link J |
| F. Cushioned limit for arm E | N. Roll |
| G. Bushing for register selector lever assembly | O. Slide which prevents automatic shifting of the register selector lever |
| H. Register selector lever | |

91.159X

Figure 16-60.—Register selector mechanism.



- register selector lever control key
arm which connects key AA to arm AC
arm which connects arm AB to slide O
- O. Slide which prevents automatic shifting of the register selector lever
AD. Roll
D. Arm which actuates pawl A
J. Link
A. Pawl which reverses the position of the register selector lever

91.160X

Fig. 16-61.—Register selector level control key mechanism.

When there is a minus balance in a selected register, interlock J safeguards the printing of debits by preventing the shifting of the register selector lever to the opposite register position after the total keys have been depressed enough to be latched down without tripping the clutch.

When the total keys are depressed, slide G is moved toward the rear by bellcrank E or F and then slide G moves interlock J forward out of the path of lip K to block the shifting of the register selector lever.

Register Meshing Controls

Register meshing controls engage and disengage the adding pinions of registers A and/or B with the adding tracks.

Engagement and disengagement of registers A and B adding pinions with the adding racks is controlled by segment G (fig. 16-63), which (through its connection to the dashpot arm assembly by link I) receives an oscillating action during each machine operation. Studs H and K on segment G actuate register A, and studs D and F on segment G actuate register B.

Positioning of lever AG (fig. 16-64) in one of its three positions (A, AB, or B) gives register selection.

As segment G moves downward at the beginning of the return stroke, stud H engages the upper pawl (E), which (by means of assemblies J and L) engages the adding pinions of register A with the adding racks. Near the end of the return stroke, stud K engages the forward finger of the upper assembly (L, fig. 16-63) to disengage the adding pinions from the adding racks.

When lever AG is moved into position A, it causes roller AF to rock arm AC which (through contact with a stud in arm AD) moves AD rearward to raise the lower pawl (E) out of the path of stud F, thus making register B inactive.

Engagement of stud F with the lower pawl at the beginning of the return stroke, and engagement of stud D with the fore finger of the lower assembly, engages and disengages the adding pinions of register B with the adding racks in the manner described for register A.

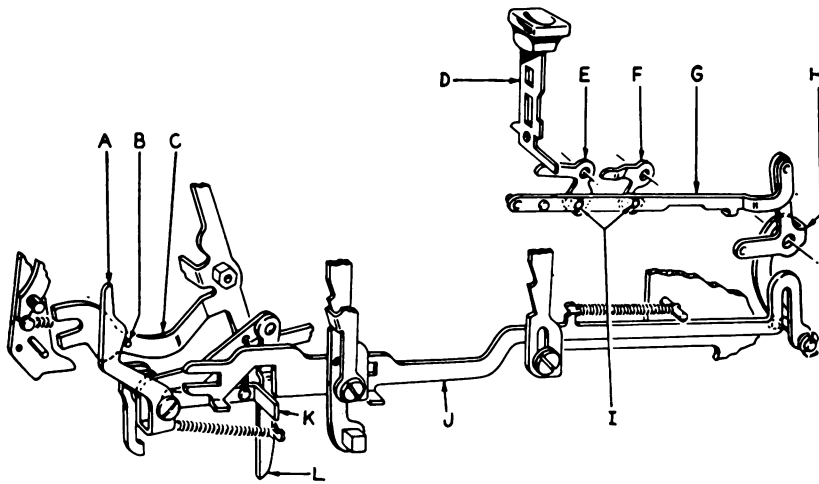
Movement of lever AG into the B position (fig. 16-65) causes roller AF to rock arm AC which moves AB rearward to raise the lower pawl out of the path of stud H, thus preventing action by register A.

If lever AG is located in the AB position (fig. 16-66), the upper and lower pawls remain at normal and are engaged during the return stroke of a machine operation by studs H and F, respectively, to engage simultaneously the adding pinions of registers A and B with the adding racks.

Disengagement of the adding pinions of both registers from the adding racks is accomplished in the same manner as described for registers A and B.

Non-Add Mechanism

The non-add key on the Series P400 adding machine permits printing of descriptive figures



- | | |
|---|--|
| A. Arm which blocks movement of lever C | H. Arm which connects slide G to interlock J |
| B. Stud on lever C | I. Studs which connect bellcranks E and F to slide G |
| C. Register selector lever | J. Interlock which blocks movement of lip K |
| D. Total key stem | K. Lip on assembly L |
| E. Bellcrank which actuates slide G | L. Arm which blocks movement of lever C |
| F. Bellcrank which actuates slide G | |
| G. Slide which rocks arm H | |

91.161X

Figure 16-62.—Register selector level interlock.

without accumulation in registers A and B. When the key is depressed, the accumulator listing pawls are disengaged to prevent meshing of the accumulator pinions with the adding racks during the return stroke.

Study figure 16-67. Depression of the non-add key stem (S) moves slide A forward through bellcrank R and stud Q to rock the rocker arm assembly. Rocking of this assembly raises register A's listing pawl out of the path of the stud which engages the pawl (to non-add register A), through finger E, stud G, finger I, and stud H. Rocking of the rocker arm assembly also raises register B's listing pawl (N) out of the path of stud O (to non-add register B), through link F, finger J, stud K, finger M, and stud L.

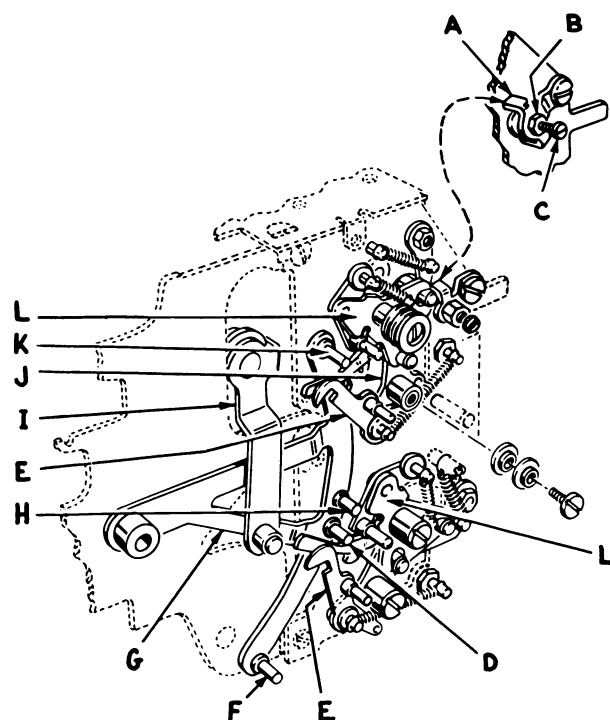
Subtract Mechanism

The subtract mechanism of the Series P400 adding machine is shown in figure 16-68. Study the nomenclature carefully.

When amounts are being subtracted in either register A or B, the upper pinions of each register are shifted to the left and the lower pinions are shifted to the right. Because the accumulator pinions are meshed with the adding racks at the beginning of a return stroke, they are turned in the OPPOSITE direction when subtracting. This shifting of the accumulator pinions is indexed from the subtract motor bar or from the total keys when a minus balance is in the machine.

Depression of the minus motor bars (fig. 16-68) rocks assembly AC; and this rocking lowers links AB and AE, which rock the bellcranks to locate spear points G to the right of arm F.

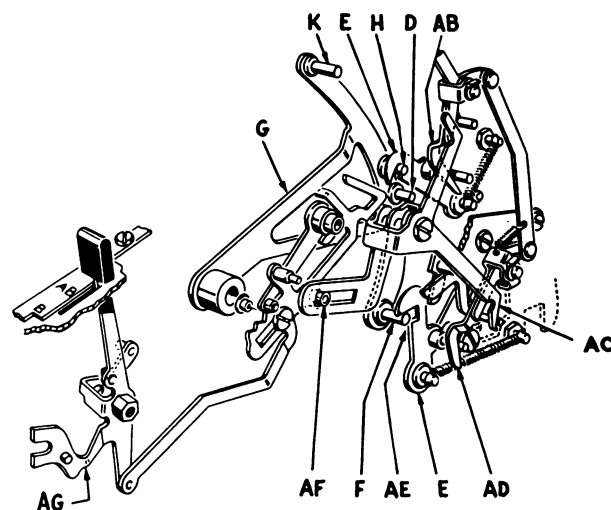
As the accumulator pinions move into mesh with the adding racks during the beginning of a return stroke, the arms which rock the bellcranks move down against the inclined surfaces on the left side of the spear points on the bellcranks to increase the rocking of the bellcranks. This increased movement of the bellcranks



- | | |
|---|--|
| A. Retainer for adjusting screw (C) | H. Stud which engages upper pawl F |
| B. Lock nut | I. Link which connects segment G to the dashpot assembly |
| C. Adjusting screw | J. Rocker arm which contains listing pawl (E) for register A |
| D. Stud which moves register B out of mesh | K. Stud which moves register A out of mesh |
| E. Listing pawls for registers A and B | L. Rocker arm which contains the total pawl for register A |
| F. Stud which engages the lower pawl (E) | |
| G. Segment which controls registers A and B | |

91.162X

Figure 16-63.—Register meshing controls.

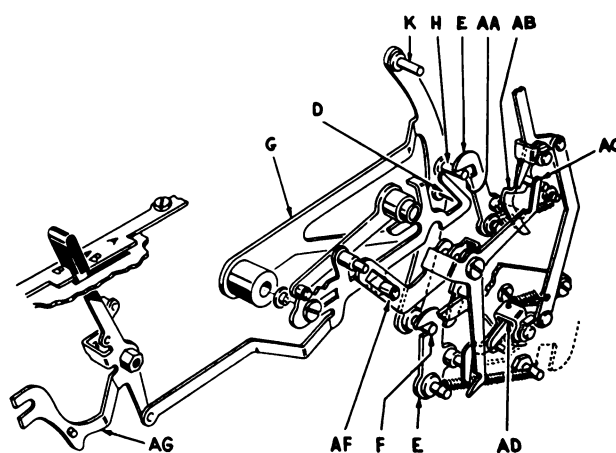


91.163X

Figure 16-64.—Meshing and unmeshing of register A during a return stroke.

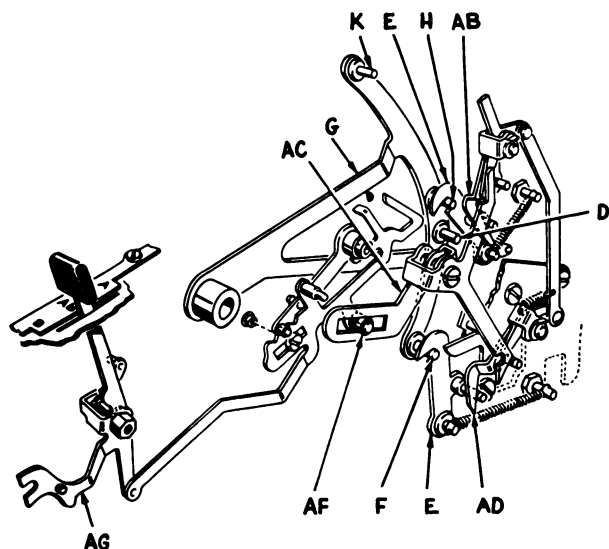
pivots the rocker arms (I) to shift the pinion shafts (H), and to locate the upper pinions to the left and the lower pinions to the right. The rocker arms are then held in their respective positions by detent springs.

When the rocker arms are pivoted to shift the pinion shafts, the upper finger of the bracket assembly (K) is pulled down into the path of the upper stud of the detent assembly which actuates links M and S.



91.164X

Figure 16-65.—Meshing and unmeshing of register B during a return stroke.



91.165X

Figure 16-66.—Meshing and unmeshing of registers A and B when the register selector lever is in the AB position.

Near the end of a return stroke, as assembly L moves to the rear, the upper finger of assembly K contacts the upper stud on assembly N, thereby moving link M rearward to raise latch W off the lip of carry rack U. Bail V, actuated only when a relay carry takes place beyond the capacity of the machine, keeps carry rack U latched at this time.

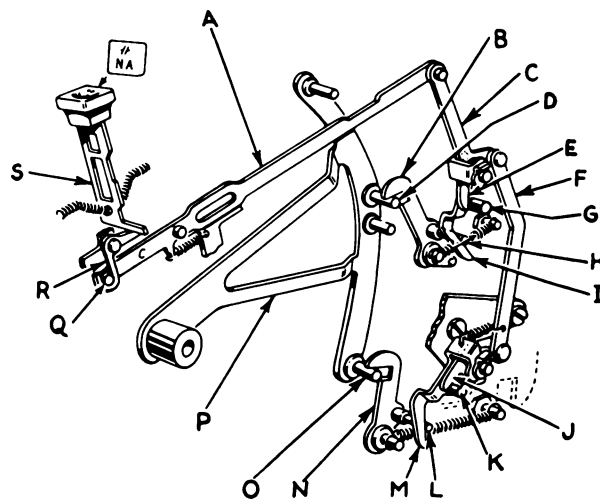
As the minus bar returns to its normal position, the bellcranks which pivot the rocker arms are positioned by springs to index shifting of the pinions to the add position.

Register Carry Mechanism

The accumulator consists of the upper register (A) and the lower register (B). The registers are identical in construction, operate independently, and produce direct MINUS totals.

Each register consists of two sets of intermeshed pinions, upper (add) and lower (subtract). See figure 16-69. Study the nomenclature carefully. Then concentrate on the information in the following sections, which give a further breakdown of the carry mechanism.

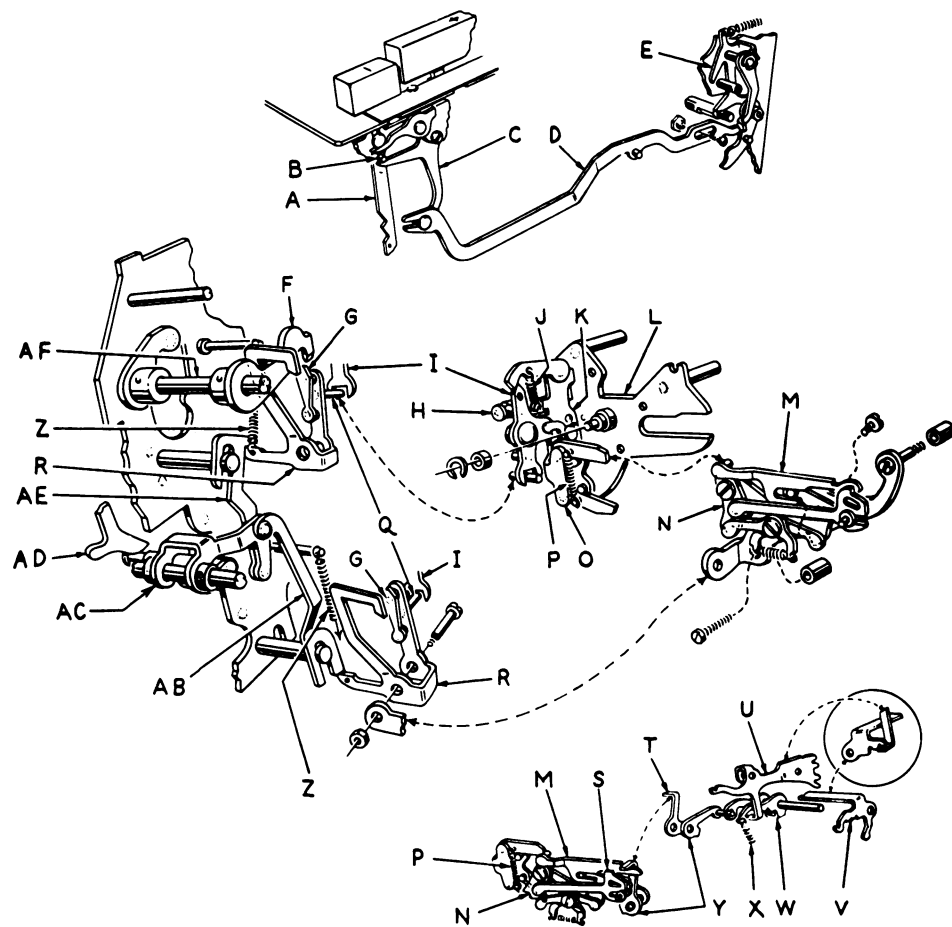
Cross-sliding action of the adding and subtracting pinions permits only one set (add or subtract) to be meshed with the adding racks during listing and total operations. The pinions



- | | |
|--|---|
| A. Slide which actuates the rocker arm assembly | J. Finger on rocker arm assembly (C) |
| B. Listing pawl for register A | K. Stud on arm M |
| C. Rocker arm assembly | L. Stud on listing pawl N |
| D. Stud which engages pawl B | M. Arm which raises listing pawl N |
| E. Finger (on rocker arm assembly) which contacts stud G | N. Listing pawl for register B |
| F. Link on the rocker arm assembly (C) | O. Stud (on segment P) which engages listing pawl N |
| G. Stud on arm I | P. Segment which controls register accumulators |
| H. Stud on listing pawl B | Q. Stud which connects bellcrank R to slide A |
| I. Arm which contacts stud H to raise pawl B | R. Bellcrank which actuates slide A |
| | S. Non-add key stem |

91.166X

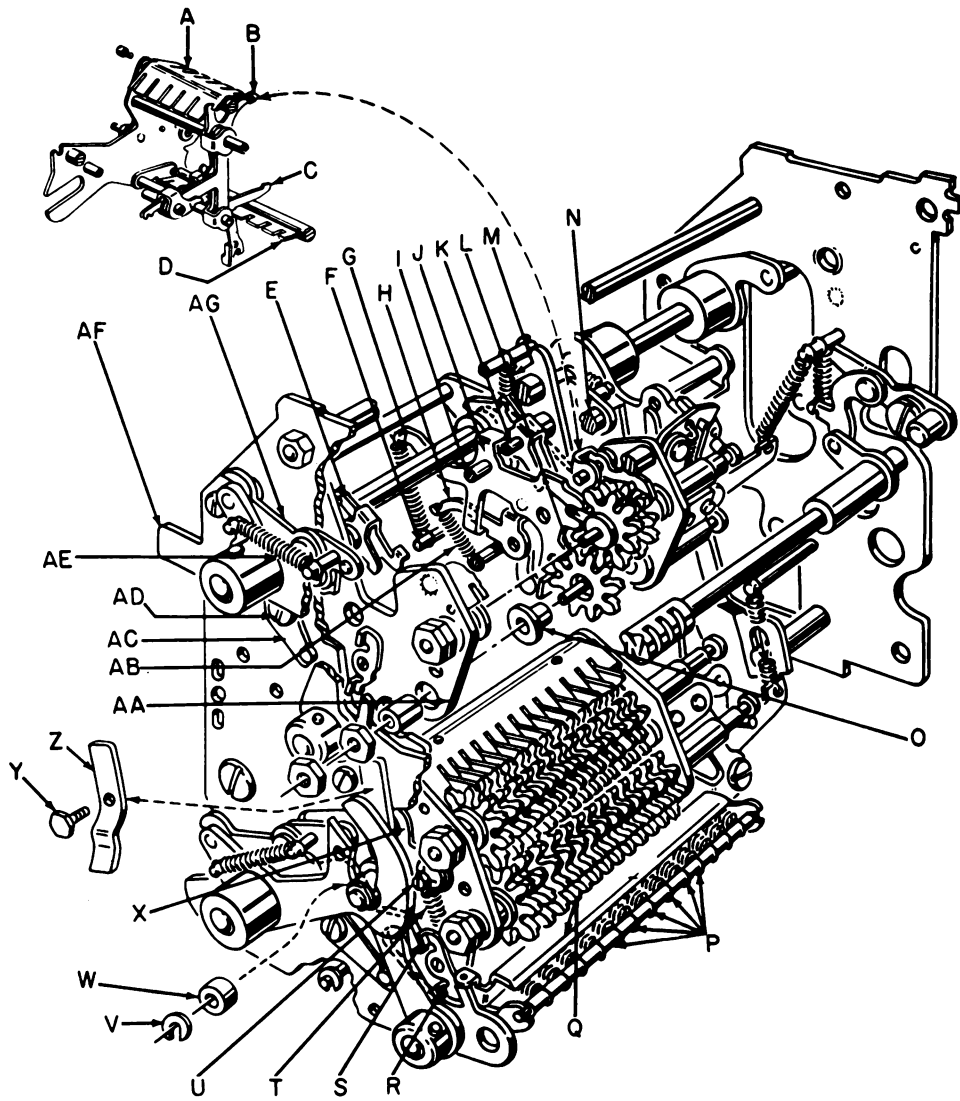
Figure 16-67.—Non-add mechanism.



- | | | |
|---|--|---|
| A. Minus motor bar | J. Detent spring which holds rocker arm | U. Carry rack in column one |
| B. Stud on minus bar which actuates bellcrank C | K. Bracket | V. Automatic one carry bail |
| C. Bellcrank which connects minus bar A to subtract arm D | L. Right side plate of accumulator section | W. Carry rack latch in column one |
| D. Subtract arm to actuating bail E | M. Link which rocks bail Y | X. Spring for latch W |
| E. Bail which rocks assembly AC | N. Detent assembly which actuates links M and S | Y. Bail which actuates latch W |
| F. Arm which rocks bellcrank R | O. Lower part of bracket K | Z. Spring which restores link assembly AB |
| G. Spear point finger assembled to bellcrank R | P. Spring which holds fingers on bracket K in position | AB. Link which actuates the lower bellcrank (R) |
| H. Adding pinion shaft | Q. Stud to pivot rocker arms (I) | AC. Bail which actuates link AB |
| I. Rocker arm which shifts adding pinion shaft | R. Bellcrank to pivot rocker arms | AD. Lower part of bail E |
| | S. Link which rocks Bail Y | AE. Link which actuates the upper bellcrank |
| | T. Lip on bail Y | AF. Accumulator control shaft for register A |
| | | |

Figure 16-68.—Subtract mechanism.

91.167X



- | | | |
|---|--|--|
| A. Guide for carry pawl (upper) | M. Spring for carry pawl latch | X. Shaft retainer |
| B. Upper carry pawl | N. Carry rack reset shaft | Y. Screw |
| C. Lower carry pawl | O. Bushing for adding pinions | Z. Guide plate which prevents excessive side play in the accumulator section |
| D. Guide for lower carry pawl | P. Lower carry pawl springs | AA. Left side plate of accumulator section |
| E. Latch for carry pawl | Q. Bail which holds adding pinions in position when they mesh and unmesh | AB. Carry rack latch spring |
| F. Spring shaft | R. Lower lip on bail Q | AC. Shaft retainer |
| G. Carry rack spring | S. Upper lip on bail Q | AD. Screw for shaft retainer |
| H. Carry rack latch | T. Spring which actuates bail Q | AE. Spring which holds link AG in position |
| I. Carry rack retaining shaft | U. Spring anchor screw | AF. Left side frame |
| J. Carry rack | V. Clip which holds roll W in position | AG. Link on the carry rack reset shaft (N) |
| K. Shaft which retains carry pawl latches | W. Roll | |
| L. Adding pinion | | |

Figure 16-69.—Carry mechanism for registers A and B.

91.168X

carry racks J (fig. 16-69), when the wheels are normal, are called in-wheels. The pinions aligned with pawls B or C are known as the ac-

adding and plus total operations, the f pinions slide to the left for mesh-adding racks. During subtracting and operations, the upper pinions slide or meshing with the adding racks.

CARRY MECHANISM.—The plus carry is illustrated in figure 16-70. An in-try is produced when the wide tooth of pinion (L, turned clockwise) rocks the (B), which (through its forked connec-rry pawl (C) moves the lower portion earward to have it latched.

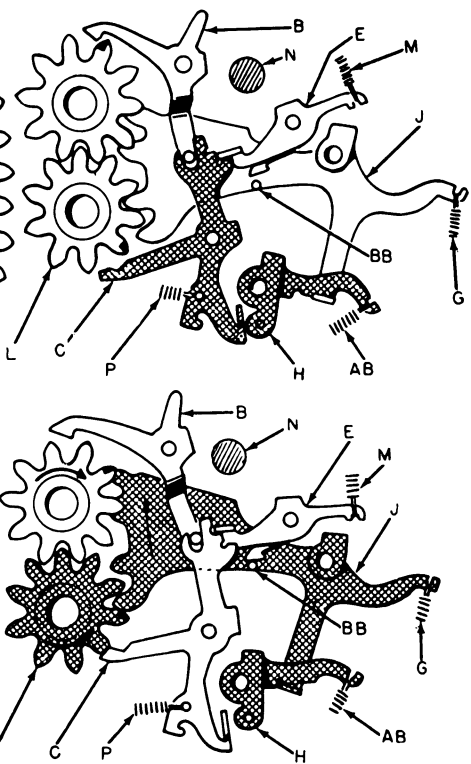
arry is completed when the lip of the of carry pawl C rocks latch H as the r moves out of mesh with the adding rocking of latch H raises its rear step e lip on the carry rack (J), allowing o rock rack J upward. Rack J then

rotates the lower pinion (L) counterclockwise. The lower pinion, in turn, rotates the upper pinion clockwise to advance it one point.

MINUS CARRY MECHANISM.—The minus part of the carry mechanism is shown in figure 16-71. An initial minus carry is produced when the wide tooth of the lower pinion rocks the carry pawl toward the rear to latch it. A minus carry is completed in the same manner as a plus carry, except that the upper pinion (meshed with the carry rack) is rotated counterclockwise. The upper pinion then rotates the lower pinion clockwise to advance it one point.

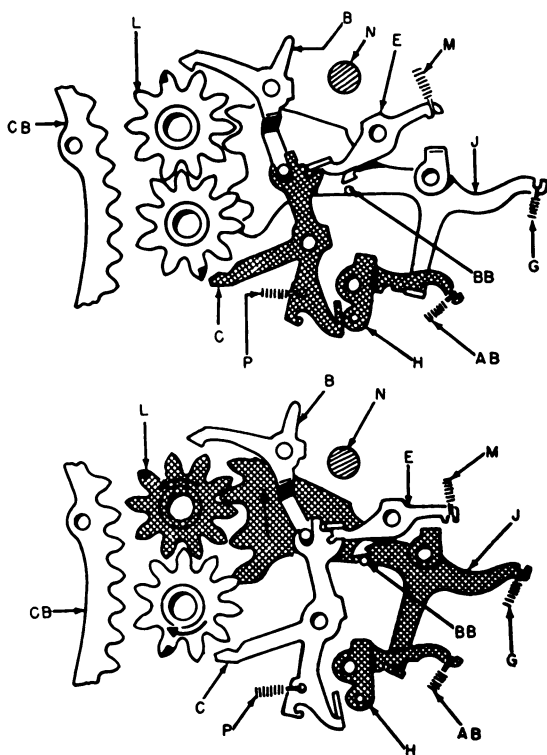
Resetting of carry pawls B and C takes place when carry rack J moves upward (fig. 16-70), raising latch E to allow spring P to pull the carry pawls back to their normal positions.

Carry racks J are reset when assembly AG (fig. 16-70) moves the accumulator into mesh with the adding racks. As AG moves forward, shaft N moves down and contacts the upper flat surface of the carry racks to move them down to permit the rear step on latches H to engage the lip of the carry racks.



91.169X

16-70.—Plus carry mechanism.



91.170X

Figure 16-71.—Minus carry mechanism.

Minus Balance Mechanism

Study the minus balance mechanism of the Series P400 adding machine in figure 16-72. This mechanism advances the first upper or lower sliding pinion one point and permits slides A and/or B to be indexed for plus or minus totals when added or subtracted amounts change the nature of the accumulated totals from plus to minus, or vice versa.

In adding machines which have 13 columns of adding capacity, a carry in the first column (automatic one) is produced in a manner similar to that of a conventional carry; that is, by releasing carry rack K, by lifting latch J through links Q or R, and by rocking bail F by carry pawl H. A carry in the first column of machines with less than 13 columns of adding capacity is produced in like manner, except that bail F is rocked by carry pawl H's rocking of latch I.

During a subtract operation, as the accumulator moves out of mesh, link R moves to the rear and engages lip N to rock bail L and to lift latch J out of engagement with the carry rack in column one (K). If the amount being subtracted exceeds added amounts accumulated during previous operations, the capacity of the accumulator is exceeded by the relay carry. This condition causes the wide tooth of the last lower adding pinion to rock pawl H, which then rocks bail F out of engagement with carry rack K, permitting this rack to be pulled up into the carried position to advance the first lower adding pinion one point.

Indexing of the minus balance mechanism in registers A and/or B is accomplished through upward movement of carry rack K, which rocks the arm (M) to lower links Q and R. This arm then moves link R down, causing link Q to move up and detent P to reverse its position. As P reverses position, it swings bail S or T to rock arm U or V forward, allowing springs (W) to pull slides A and/or B forward to locate their upright projections under the total keys. When the total keys are depressed, slide A or B is lowered and link E is indexed into the subtract position through the rocking of the bellcrank which actuates link E.

As the accumulator moves out of mesh during the first added-amount operation following a minus-balance total operation, link Q raises latch J through bail L. When the amount being added exceeds the capacity of the upper adding pinions, the relay carry causes the wide tooth of the last upper pinion to rock carry pawl G, which

causes carry pawl H to rock bail F out of engagement with carry rack K to permit carry rack K to be pulled up and to advance the first upper adding pinion one point. At the same time, carry rack K moves link Q down to reverse the position of detent P, which then rocks bail S or T to move slide A or B back to the normal position to normalize the minus balance mechanism.

Total Timing Mechanism

The total timing mechanism of a Series P400 adding machine safeguards against complementary results by preventing the depression of the TOTAL and SUBTOTAL keys until slides A and B (fig. 16-72) have assumed their correct positions during plus and minus balance operations. Refer to the mechanism illustrated in figure 16-73 as you study its operation.

During a forward stroke, slide F is moved to the rear by roll E and is latched in this position by lip I. As slide F moves rearward, stud J is placed in the rear part of the internal cam in the timing arm (N), and stud K is moved away from tail L to permit spring C to raise lip A into the path of slide B to block depression of the total and subtotal keys.

Lip I is disengaged from slide F at the end of the return stroke, by roll E's contact with finger D. This disengagement permits spring H to pull slide F forward, but the forward movement of the slide is retarded by stud J as it travels in the internal cam in the timing arm. If it is necessary that the forward movement of slide F be retarded further, weights M, O, and P may be added.

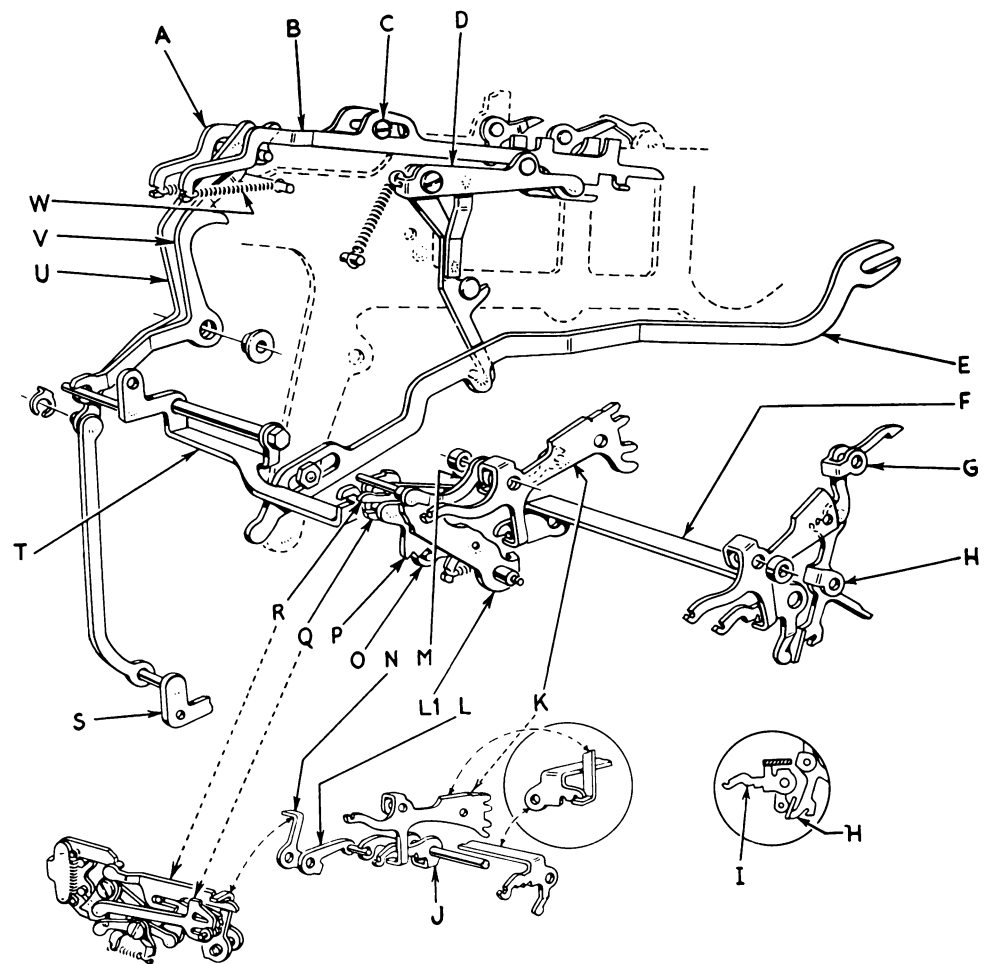
As slide F returns to normal, stud K contacts tail L to lower lip A out of the path of slide B, permitting depression of the total keys.

Drive Clutch Trip Mechanism

Study the drive clutch trip mechanism of the Series P400 adding machine in figure 16-74.

When a motor bar or a control key is depressed, the action lowers link AF and arm AI. Arm AI then moves latch AH down and out of engagement with the square stud in arm AE, thus permitting arm AE to be pulled down in position for turning shaft assembly AJ. When shaft AJ turns, it raises arm AK to disengage hook B from the stud in arm A; this allows the clutch dog to engage the drive gear and the switch points to close the circuit and run the motor and machine.

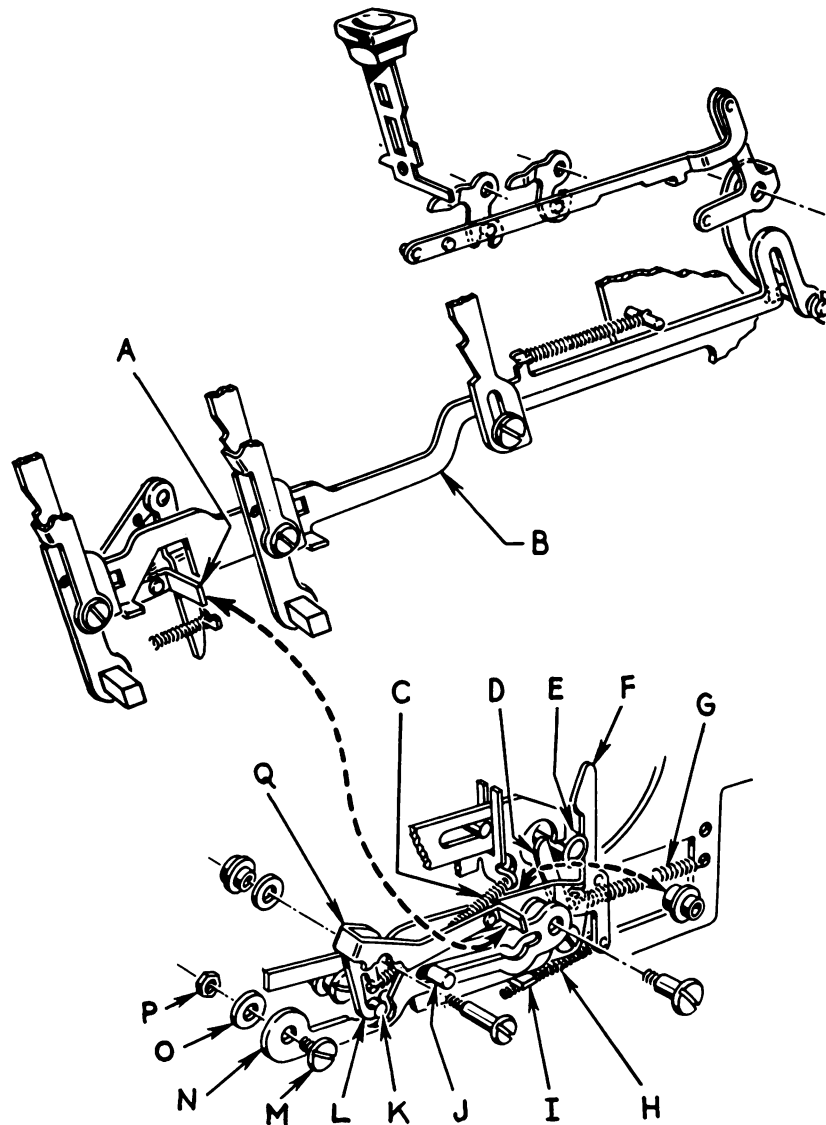
During a return stroke, the roll on arm AD rides over pawl AC to provide sufficient time for the completion of a relay carry.



- | | |
|--|---|
| A. Minus balance total slide (register B) | L. Bail which actuates latch J |
| B. Minus balance total slide (register A) | L1. Brace |
| C. Screw which holds slide B | M. Arm which lowers links Q and R |
| D. Bellcrank which actuates link E | N. Lip on bail L |
| E. Link to index subtract mechanism | O. Detent arm |
| F. Automatic one carry bail | P. Detent which holds links Q and R in position |
| G. Upper carry pawl | Q. Link which rocks bail L |
| H. Lower carry pawl | R. Link which rocks bail L |
| I. Carry rack latch used in machines which have less than 13 columns | S. Bail which actuates slide A |
| J. Carry rack latch in column one | T. Bail which actuates slide B |
| K. Carry rack in column one | U. Arm which restores slide A to normal position |
| | V. Arm which restores slide B to normal position |
| | W. Spring which pulls slide B into the minus balance position |

Figure 16-72.—Minus balance mechanism.

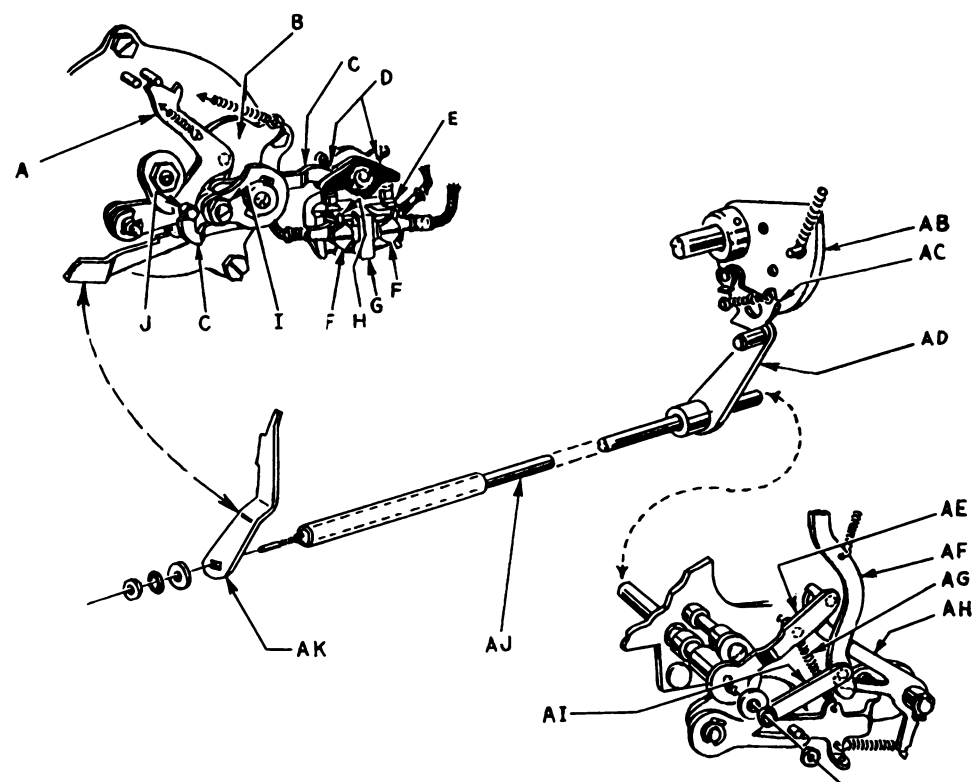
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- | | | |
|--|--|---|
| A. Lip which blocks forward movement of interlock B | E. Roll on secondary mechanism | L. Tail on timing arm |
| B. Interlock which prevents simultaneous depression of total keys and motor bars | F. Timing slide to control timing arm | M. Screw which holds washer O and nut P |
| C. Spring which rocks timing arm (Q) | G. Spring on latch D | N. Timing arm which controls timing slide F |
| D. Latch which holds timing slide to the rear | H. Spring which restores slide F | O. Washer used for added weight to timing slide F |
| | I. Lip on latch D | P. Nut which holds washer on screw M |
| | J. Stud on slide F | Q. Timing arm which controls interlock B |
| | K. Stud on slide F which holds timing arm normal | |

Figure 16-73.—Total timing mechanism.

91.172X



- | | |
|-----------------------------|--------------------------------|
| A. Arm which holds hook | I. Eccentric bushing |
| B in normal position | J. Rollon arm A |
| B. Hook which controls | AB. Timing cam on secondary |
| release of clutch dog. | mechanism |
| C. Upper switch point | AC. Pawl which delays |
| assembly | tripping of drive clutch |
| D. Springs which connect | AD. Limit arm on shaft AJ |
| upper switch point | AE. Arm which holds trip shaft |
| retainer to the | AJ in normal position |
| switch point arm | AF. Link on intermediate |
| E. Lower front switch point | motor bar assembly |
| F. Screw which retains | AG. Spring which pulls arm AE |
| lower front and | AH. Latch which retains arm |
| rear switch points | AE in normal position |
| G. Lower switch points | AI. Arm which disengages |
| retainer | latch AH from arm AE |
| H. Lower switch point | AJ. Clutch trip shaft |
| (rear) | AK. Clutch trip arm |

Figure 16-74.—Drive clutch trip mechanism.

91.173X

For additional information on the drive clutch trip mechanism, and all other parts and mechanisms, refer to the manufacturer's technical manual for the specific machine.

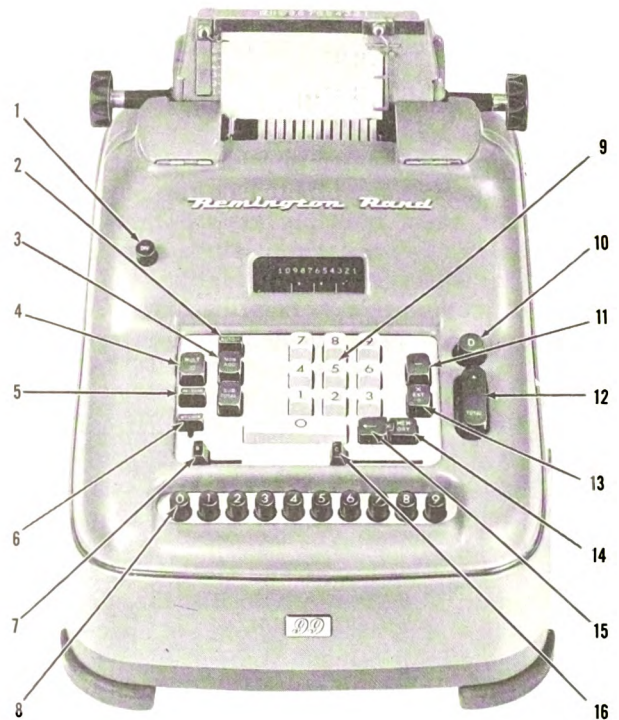
CALCULATORS

Because of the nature of the work which a calculator must perform (multiplying, dividing, subtracting), it is a very intricate machine. Many precision-made parts and mechanisms are required for the accomplishment of division or subtraction, for example. When the operator of a calculator depresses bars or keys on the keyboard (with the motor running), he sets in motion specific links, levers, bellcranks, cams, pawls, segments—whatever combination of all these parts is required, including gears and other parts, for accomplishing a specific function.

There are several good makes of calculators, including Friden, Monroe, Burroughs, and Remington; and the Navy purchases different makes and models of calculators. These machines, while different in some respects, have many similar mechanisms and parts, because the operations they must perform are the same.

Before you can analyze and remedy casualties to and adjust such a complex machine as a calculator, you must understand the function and operation of its parts and mechanisms. The only way you can find out the purpose and principle of operation of a part, or mechanism, in the machine is to study carefully how the part functions individually and/or collectively in order to perform the function for which it was designed.

A model DM99 Remington calculator is illustrated in figure 16-75. This machine is considered to be one of the newest and best calculators made; and the technical manuals which explain the operation of parts and mechanisms also contain excellent instructions for disassembling, reassembling, inspecting, and adjusting. (NOTE: A thorough understanding of the Model 3 adding machine, "Remington Instruction Manual #DM-176," is a prerequisite to understanding the Model 98 adding machine, "Remington Instruction Manual #DM254," which is, in turn, a prerequisite to understanding the Model 99 Calculator, "Remington Instruction Manual #DM131, Rev. 1.")



- | | |
|------------------------|--------------------------------------|
| 1. Division key | 9. Regular 10 key keyboard for speed |
| 2. Total control key | 10. Decimal key |
| 3. Non-add key | 11. Subtract key |
| 4. Mult. total key | 12. + and total motor bar |
| 5. Release key | 13. x ext. $\div$ key |
| 6. Sub-total key | 14. Memory key |
| 7. Back space key | 15. Space key |
| 8. Multiplication keys | 16. Correction key |

91.372X

Figure 16-75.—Remington Model DM 99 calculator.

Some important features of the Model DM99 calculator are:

1. Automatic Multiplication.—If you enter a multiplicand on the keyboard of a Model DM99 Remington calculator and then depress the space key once for each digit in the multiplier

less one), you can multiply automatically by depressing the multiplication keys which represent the value of each digit in the multiplier (in order of reading). The answer is printed automatically and the machine clears itself in readiness for the next operation.

If the operator desires to clear the machine before a problem is completed, he can clear it by pulling the release key forward before he depresses the last multiplier digit.

2. Short-cut Multiplication.—Short-cut multiplication is accomplished on the Model DM99 calculator when multiply keys 6 through 9 are used. NOTE: Depression of other keys is not required for short-cut multiplication.

3. Accumulative Multiplication.—Accumulative multiplication is achieved on the Model DM99 calculator through use of the TOTAL CONTROL lever. If you position the total control lever to the left, the machine cannot automatically total after each multiplication operation. Before you multiply the last digit of a series of operations, move the total control lever to the right to get an automatic grand total.

4. Mult-total Key.—The mult-total key simplifies multiplication by allowing the operator to use space and memory keys to set spaces to the right of the multiplicand. A mechanism for eliminating zero print to the right of the product on total operations is also included with this feature.

5. Simpla-type (Printing Control).—The printing control feature on the Model DM99 machine permits the printing of essential factors and results ONLY on the tape. During multiplication, for example, the multiplicand is printed ONLY once—there is NO repetition of printing after each backspacing. The multiplier is printed along with the product. During division, the divisor is printed ONLY once.

MECHANISMS AND PARTS

Discussion of the operation of all parts and mechanisms in a calculator, in sufficient detail for you to be able to understand it, requires considerable space. Therefore, the information in this section is limited. In addition to the features presented for a Model DM 99 Remington calculator, a discussion of the important parts and mechanisms of a Friden calculator is included in the paragraphs which follow. If you understand the operation of the mechanisms of one machine, you will be able to work with other machines as long as a manufacturer's technical manual is available for a particular model.

The UPPER DIALS (ACCUMULATOR DIALS) show totals, subtotals, individual products, accumulated products, negative products, and simultaneous individual and accumulated products.

When set, the AUTOMATIC ROUND-OFF, or FRACTIONAL CENT DIAL, will automatically round-off answers appearing in the accumulator dials.

In addition to the automatic round-off feature, each upper dial is equipped with an extension, or DIAL TWIRLER, that enables an operator to make entries or adjustments manually.

The LOWER DIALS (counter dials) show the number of items added or subtracted, individual multipliers, individual quotients, negative quotients, accumulated quotients, subtracted quotients, grand totals of products, and square roots.

The COUNTER CONTROL KEY, when positioned rearward, permits a normal position count in plus and a negative count in minus. The forward position reverses the count so that the plus count is negative and the minus count positive. The center (gradient) position is a special feature which provides a positive count in both plus and minus operations.

The COUNTER NON-ENTRY KEY, when positioned forward, prevents the entry of multipliers or counted items in the lower dials. This feature allows the lower dials to be used for accumulating products and totals.

The MAIN KEYBOARD (Selecting Keys) is used for entering amounts into the machine where they may be added, subtracted, multiplied, divided, and squared.

As far as the COLUMN CLEAR AND LOCK KEYS are concerned, each key, when locked or depressed, locks or clears the selection in that particular keyboard column. On models with the "back transfer" feature, the product to the keyboard is disabled when a column clear and lock key is raised.

The KEYBOARD LOCK KEY, when moved forward, locks the entire keyboard and prevents operation of the product to the keyboard key and the square root keys in models with the back transfer and square root features. This key also prevents entry of the keyboard value into the accumulator dials when the enter dividend key is used.

The KEYBOARD CLEAR KEY clears the entire keyboard with a single depression. It also clears any transferred or stored figures under the keyboard in models with back transfer or square root features.

The PLUS KEY adds any amount set on the keyboard into the upper dials and records the number of items added in the lower dials. The plus key is also used for semiautomatic multiplication.

The MINUS KEY subtracts any amount set in the keyboard from the upper dials and reverses the count in the lower dials. The minus key is also used for semiautomatic negative multiplication.

The ADD KEY, when positioned forward, permits only a single cycle operation in addition and subtraction, and provides automatic keyboard clearance at the completion of most power key operations. When the add key is positioned rearward, it allows continuous cycling in addition or subtraction, and disables the automatic keyboard clearance feature.

The CARRIAGE SHIFT KEYS shift the carriage to the right or left. The carriage can be stopped in any position.

The CARRIAGE CLEAR KEY returns the carriage to the extreme left, or "home" position, clears the upper and lower dials, and automatically clears the keyboard.

OPTIONAL CLEAR KNOBS are provided so that the upper dials may be locked for accumulating sums and products. The lower dials may be locked for accumulating multipliers, quotients, and grand totals. This makes it possible for one half of the upper dials to be cleared while figures are retained in the other half (split clear marker indicates separation).

As far as AUTOMATIC MULTIPLICATION is concerned, with the multiplier entered into the multiplier keyboard and the multiplicand set in the main keyboard, operation of the multiply key instantaneously starts and completes a fully automatic multiplication operation in which the product appears in the upper dials and the multiplier in the lower dials.

The MULTIPLIER KEYBOARD is used for entering figures of the multiplier as they are read from left to right. Each digit appears in the multiplier check dials as predetermined, visible proof of accuracy.

The MULTIPLY KEY automatically shifts the carriage to "home" position, clears the upper and lower dials, performs an individual multiplication problem, and clears the keyboard.

The ACCUMULATE MULTIPLY KEY automatically shifts the carriage to "home" position, starts and completes a multiplication in which the product and multiplier add to prod-

ucts and multipliers already in the dials, and clears the keyboard.

The NEGATIVE MULTIPLY KEY automatically shifts the carriage to "home" position, starts and completes a negative or subtractive multiplication in which the product and the multiplier are subtracted from products and multipliers already in the dials, and clears the keyboard.

The REPEAT MULTIPLIER KEY, when positioned forward, locks a multiplier into the multiplier dials for any number of multiplications required.

The MULTIPLIER CLEAR KEY instantaneously clears the multiplier dials for a correction.

The CLEAR-MULT KEY is used on certain models for performing carriage clear, positive multiplication, or negative multiplication operations. The type of operation that the clear-mult key will perform is determined by the position of the MULTIPLIER SETTING KEY as follows: Forward position—negative mult; rearward position—positive mult; center position—carriage clear.

The TAB STOP KEYS are used individually in enter dividend and back transfer operations to stop the tabulation (right shift) of the carriage at a predetermined point; use in pairs in division and selective transfer to stop the operation short of the usual first counter dial.

The ENTER DIVIDEND KEY automatically shifts the carriage to "home" position, clears the upper and lower dials, tabulates the carriage to a preset tab stop key, enters the dividend into the upper dials while preventing a count in the lower dials, and clears the keyboard.

Simultaneous operation of the DIVISION KEYS automatically aligns the divisor in the keyboard with the dividend in the upper dials, starts and completes a division in which the quotient appears in the lower dials, and clears the keyboard. If the left division key is used independently, the quotient is negative and appears as a complement in the lower dials. The division key is also used to subtract a quotient from a quotient (s) already in the lower dials. In certain machines, the right (positive) division key operates independently for positive division operations and the left (negative) division key operates as described previously for negative calculations.

The DIVISION STOP KEY, when positioned forward, will stop a division when the operator desires to read the quotient as a whole number

the remainder before reducing the remainder decimal. The division stop key also stops machine when a division is started where divisor was not entered into the keyboard. Moved rearward, the division stop key will cause the enter dividend key, the carriage return key, and the mult keys. When the division key and the add key are both positioned forward, the machine cycles once in plus and minus operations, but the keyboard does not return.

DECIMAL POINT CONTROL

The location of the decimal points for any sequence of machine operations can be easily determined and programmed by using the following rules. Decimal point control is the essence of successful machine operation, and the information which follows will cover the important aspects of this area.

Addition and Subtraction

In addition and subtraction, all amounts must be entered around the same decimal point on the keyboard, and the carriage must remain in the same position throughout the calculation. The decimal in the answer (in the upper dials) must be located directly above the decimal marker on the keyboard.

Multiplication

In multiplication, the product appears in the upper dials where the decimal point is determined by taking the sum of the decimal places of the two factors. Place the decimal marker to the left of the dial number corresponding to the sum. Therefore,

$$\text{Keyboard} + \text{Multiplier} = \text{Upper Dials}$$

Before commencing work, choose decimal positions that will allow for the maximum number of decimal places in each factor. If factors are entered correctly around these positions, the products will appear around the predetermined decimal point in the upper dials.

Division

In division, depress the tab stop key corresponding to the number of decimals desired in the answer, and set a decimal marker directly above it in the lower dials. Set the keyboard decimal marker to allow for the maximum number of decimals in each term. Count to the left of the depressed tab stop key the same number of decimal places that are in the keyboard, and set a decimal marker in the upper dials. Place the dividends and divisors around the decimal point in the keyboard, using the enter dividend and divide keys to perform the operations. The dividends and quotients will appear around their predetermined decimal points in the upper and lower dials.

If the dividend is a product already in the upper dials (or entered by twirlers), determine the decimal point in the quotient as follows:

$$\text{Upper Dials} - \text{Keyboard} = \text{Lower Dials}$$

ROTO-FLOW DRIVE

Roto-flow drive is a term used by Friden to describe the drive principle of the Friden calculator. Very simply, it means that all the main rotating parts revolve in one direction at all times, whether the operation be addition, subtraction, or the shifting of the carriage from right to left. The principle of the roto-flow drive also applies to multiplication and division, as these operations are accomplished by controlling the basic functions of addition, subtraction, and carriage shifting.

Answers to addition and subtraction problems are registered in the accumulator dials, which must be capable of being rotated in two directions. The direction of rotation is controlled by the add-subtract gears. Each add-subtract gear, which is actually two gears on one hub, rotates in one direction only. If the lower gear is moved into mesh with the accumulator dial, the dial will register addition. If the upper gear is moved into mesh, the accumulator dial will register subtraction. The direction of movement of the add-subtract gears is controlled by the add-subtract gate.

Additional information concerning the control of the amount of rotation of the add-subtract gears and the accumulator dials, as well as the operation and maintenance of the mechanism, can be obtained from the operations manual for the specific equipment.

CHAPTER 17

SECURITY

As a petty officer, you are required to have some knowledge of security measures and regulations. This chapter provides selected information on aspects of security that you must know about in order to advance. For additional information on security, consult OpNav Instruction 5510.1C (or later edition), Department of the Navy Security Manual for Classified Information.

PURPOSE OF SECURITY PROGRAM

The security program deals basically with the safeguarding of information that should not be allowed to fall into the hands of foreign governments or foreign nationals because of the danger that such information might be used to the detriment of the United States. All military personnel should be indoctrinated with the fundamentals of security so that they will automatically exercise caution in everything that relates to security information.

Information may be compromised through careless talk, through actual subversion by enemy agents, by careless handling of classified material, and in various other ways. Some of the ways in which military personnel may accidentally give away vital information are discussed in Basic Military Requirements, NavPers 10054-C. The remainder of this chapter deals with ways in which U. S. military personnel might be subverted, with the disciplinary actions that result from violation of security regulations, and with the custody, control, and transmission of classified information.

SUBVERSION OF MILITARY PERSONNEL

There are a number of ways in which agents of foreign governments may attempt to subvert military personnel in order to gain access to security information. If you understand some of the methods used by foreign agents, you can be

on the alert for actions that might get you involved with subversive parties.

To begin with, it should be remembered that cost, time, and effort are no obstacles to a foreign government that is really out to get vital information. Trained agents may be sent to areas near military installations, where they may spend weeks, months, or even years establishing themselves and becoming friendly with military personnel.

One of the commonest methods of subversion involves getting a hold over a person who might be in a position to obtain classified information. The hold can be almost anything—excessive drinking, illicit personal relationships, the use of drugs, or excessive monetary indebtedness, to name but a few of the habits or actions that have gotten people into trouble. A person with a problem of this sort is fair game for foreign agents, since he can be blackmailed into doing things that are in violation of security regulations.

Trained foreign agents know how to exploit weaknesses wherever they find them. For example, consider a petty officer who has gotten deeply in debt through gambling or just poor budgeting. The agent may skillfully get the man even deeper in debt, then lend him money to help him get out of trouble. Eventually the petty officer will find himself in a position where he feels that he cannot refuse to give the agent small and relatively unimportant pieces of information. The information requested is usually minor, at first; but the demands increase as time goes on, and the petty officer may finally become so involved and so trapped that he ends up giving vital information to a foreign agent.

A person who is married and has family obligations is a prime target for another approach. He may be taken to parties or other social gatherings and introduced to women who, unknown to him, are actually foreign agents or

in the pay of foreign agents. If the military man becomes sufficiently involved with one of these women, all meetings and actions are recorded and photographed without the victim's knowledge. When sufficient evidence has accumulated, the victim is blackmailed into turning over information. Small bits of relatively unimportant information may be requested at first; but it will not be long before more vital information is demanded.

As may be seen from these examples, a person who has been selected to be a source of information to a foreign agent is in a very difficult position. His weak points are emphasized and played upon until he feels completely trapped. In desperation, he feels that he has no other course of action except to cooperate and furnish information to the foreign agent.

However, this is not true. There is always one honorable way to get out of this kind of difficulty. If you should ever find yourself entangled in such a situation, **DO NOT ALLOW YOURSELF TO BE BLACKMAILED**. Tell the whole story to your division officer, legal officer, or security officer, or the nearest Naval Investigative Service Office. Don't try to handle the situation by yourself; your chances of being able to outwit a highly trained foreign agent are just about zero. So tell your story fully and completely, including any wrong actions of your own, and accept the consequences. Remember that whatever wrong actions you may have committed up to this point are nothing compared to the act of actually cooperating with a foreign agent.

NEED-TO-KNOW CONCEPT

The need-to-know concept requires that only those persons whose official military or other governmental duties require it shall be given access to any piece of classified information. The responsibility for determining whether a person's duties require that he possess or have access to classified information and whether he is authorized to receive it rests upon each individual who has possession, knowledge, or command control of the information involved and NOT upon the prospective recipient. This principle applies whether the prospective recipient is an individual, a command, a defense contractor, another Federal agency, or a foreign government.

A need to know is recognized as being established when (1) the disclosure is necessary in the interests of national defense; (2) there clearly appears from the position, status, duties, and

responsibilities of the applicant that he has a legitimate requirement for access to the classified information in order to carry out his assigned duties and responsibilities; (3) there is no other equal or ready source of the same classified information available to him; and (4) the applicant is or can be appropriately cleared for access to the degree of classified information involved and is capable both physically and mentally of providing the degree of protection which that information requires.

DISCIPLINARY ACTION FOR SECURITY VIOLATIONS

Any person who is found to be responsible for the loss, unauthorized disclosure, or possible compromise of classified information and any person who violates security regulations shall be promptly and adequately disciplined, regardless of rank or rate or position. Even where it is impossible to identify a specific individual as the source of an unauthorized disclosure of classified information, disciplinary action may still be in order. Where the source can be traced to a particular command or office, the commander or official in charge shall be held responsible for any dereliction in the discharge of his responsibilities. In the case of military personnel, disciplinary action may include trial by court-martial.

CUSTODY AND CONTROL OF CLASSIFIED MATERIAL

Each person in the Naval Establishment is individually responsible for assuring that all classified information which he prepares, receives, or handles is properly accounted for in accordance with the requirements of the Department of the Navy Security Manual for Classified Information. Each person is also responsible for ensuring that such classified information is made available only to persons who have appropriate security clearances and who have clearly established a need to know.

Classified material must not be removed from the physical confines of a command without the knowledge and approval of the commanding officer or his authorized representative. When classified matter is so removed, as when it is taken to conferences or to other offices, a complete list (receipt) must be prepared, signed by the individual removing the material, and appropriately filed until the material is returned.

During working hours, each person using classified information must take the following precautions to prevent deliberate or casual access to classified information by unauthorized persons:

1. Classified documents removed from stowage for working purposes must be kept under constant surveillance or face downward or covered when not in use.

2. Visitors not authorized access to the particular classified information within a working space shall be received or interviewed in specially arranged reception rooms or areas.

3. Preliminary drafts, carbon sheets, carbon paper typewriter ribbons (one-time), plates, stencils, stenographic notes, worksheets, and all similar items containing classified information must be either (1) destroyed by the person responsible for their preparation, immediately after they have served their purpose, or (2) given the same classification and safeguarded in the same manner as the classified material produced from them.

4. New typewriter ribbons used in the preparation of classified material must be either (1) typed over until illegible, or (2) given the same classification and safeguarded in the same manner as the classified material prepared with them.

5. If for any reason a room must be vacated during working hours, the classified material therein must be stowed in accordance with security regulations.

After working hours, the custodians of classified material must make an inspection to ensure that the following minimum requirements are met:

1. All classified material is stowed in the proper manner.

2. All classified material that must be passed from watch to watch is accounted for in the proper manner.

3. Burn bags are properly stowed or destroyed.

4. The contents of wastebaskets that contain classified material are properly stowed or destroyed.

5. Classified shorthand notes, carbon paper, carbon paper typewriter ribbons, rough drafts, and similar materials have been properly stowed or destroyed. (As a matter of routine during working hours, such items should be placed in

burn bags immediately after they have served their purpose.)

The control of classified material is necessary for several reasons. It must be controlled to limit dissemination and to prevent excessive production or reproduction. It must be controlled so that, when regraded or declassified, the holders or recipients can be ascertained and notified. Classified material must be controlled so that the office or person normally responsible for its security can be ascertained.

Top Secret material must contain a disclosure sheet and must be continually controlled so that its location can be determined properly and so that those who have access to its contents can be ascertained. These requirements can generally be fulfilled by effective supervision, conscientious and informed execution of personal responsibilities, and efficient administration.

In addition, the importance of Top Secret material requires a formal record for hand to hand transfer of custody from one accountable office or command to another. Secret material also requires a record of transfer of custody from one accountable command to another. For Top Secret material, there is established a special system for recording those who have access to the Top Secret material.

The accounting system for an activity should provide readily available information on: what classified material it has received, what classified material it has produced, who has custody of a particular Top Secret document, and what disposition has been made of Top Secret and Secret material.

Within individual commands, the commanding officer shall establish such control procedures, to include inspections, which will ensure that accounting of Top Secret meets minimum requirements in accordance with the current OP-NAVINST 5510 (chapter 4 of Security Manual For Classified Information).

Additional information dealing with the accounting for Secret, Confidential, and Top Secret Restricted Data originated by the Atomic Energy Commission can also be obtained from the Security Manual For Classified Information.

TRANSMISSION OF CLASSIFIED MATERIAL

Some of the regulations governing the transmission of classified materials within and between the 48 contiguous states and the District

of Columbia or wholly within Alaska, Hawaii, the Commonwealth of Puerto Rico, or a United States possession are listed below. For additional information on the transmission of classified material, see the Security Manual.

TOP SECRET information may be transmitted by U. S. military personnel (E-7 and above) and by U. S. civilian employees (GS-7 and above) who have been cleared for access to Top Secret information. In addition, military personnel in pay grades E-5 and E-6 and U. S. civilian employees in grades GS-5 and GS-6 who have been cleared for access to Top Secret information may transmit such information between Department of Defense elements located in relatively close proximity to one another, provided the transmission is accomplished during normal daytime duty hours on the same day. Persons whose primary duties involve the transmitting or escorting of Top Secret Material will be specifically designated in writing. Department of Defense contractors' employees who have been specifically designated in accordance with the provisions of the Department of Defense Industrial Security Manual may also transmit Top Secret information. The Armed Forces Courier Service may transmit Top Secret information provided it qualifies in accordance with effective OpNav

directives. Top Secret information may also be transmitted by electrical means in appropriate encrypted form.

SECRET information may be transmitted by any of the means approved for the transmission of Top Secret material and by (1) appropriately cleared military, civilian, or contractor personnel; (2) U.S. registered mail; (3) electrical means over approved communication circuits; (4) Armed Surveillance Service or Protective Signature Service of the REA, INC. (including the Air Express Division of REA, INC.); (5) commercial carriers that have DOD Secret Facility Clearances; and (6) Government Carriers.

CONFIDENTIAL information may be transmitted by any of the means approved for transmission of a higher classification and by (1) U.S. certified mail (except certain categories of Confidential information); and (2) commercial carriers for bulky materials (except for certain categories of Confidential bulky materials).

FOREIGN RESTRICTED material may be transmitted by one of the means established for Confidential and by U. S. first class mail.

Classified material must be properly prepared before it is transmitted by any of the above means. Detailed instructions for preparing classified material for transmission or shipment are given in the Security Manual.

APPENDIX I

GLOSSARY OF TERMS

WATCHES AND CLOCKS

ADJUSTMENT OF BALANCE ASSEMBLY—The manipulation of the balance wheel with its spring and staff to secure the most accurate timekeeping possible. Three adjustments are usually made: for isochronism, temperature, and position.

ADJUSTMENT FOR ISOCHRONISM—Manipulating the balance and balance spring so that the watch does not change its rate when the balance swings through a long arc or a short one.

ADJUSTMENT FOR POSITION—Manipulating the balance and balance spring so that the rate does not change when the watch is in different positions.

ADJUSTMENT FOR TEMPERATURE—Arranging the screws on the compensation balance so that the time of swing will be as nearly as possible the same for a considerable range of temperature. (Seldom necessary today.)

ALLOY—A mixture of two or more metals.

ARBOR—The axle on which a wheel turns.

ARKANSAS OILSTONE—A smooth oilstone (hard or soft) used for sharpening gravers, screw drivers, and tools of all kinds to a final finish.

BACKLASH (WATCH)—A small reverse movement of the wheels at the end of unwinding.

BALANCE ARC—In detached lever escapements, that part of the vibration of the balance in which it is connected with the train.

BALANCE ARM—The flat piece of metal across the center of the balance wheel which supports the balance wheel on the balance staff.

BALANCE ASSEMBLY—The balance wheel and its arbor, complete with hairspring and roller assembly.

BALANCE COCK—The projecting bar which holds one end of the balance arbor.

BALANCE SPRING—(Also called hairspring.) A fine, coiled wire, one end of which is

attached to a collet fitted friction-tight on the balance staff and the other end to a stud on some stationary part of the watch, (as on balance cock or watch plate.) This spring governs the time of vibration of the balance.

BALANCE STAFF—The axis or arbor which carries the balance wheel.

BALANCE TRUING—Bending balance wheel rims back into shape to obtain perfect balance.

BALANCE WHEEL—The oscillating wheel of a watch, which, along with the balance spring, regulates the motion of the train, thus controlling the movement of the hands.

BANKING—The striking of the outside of the lever by the impulse pin due to excessive vibration of the balance.

BANKING PINS—Pins (two in number) which arrest or limit the angular motion of the lever in the lever escapement of a watch.

BANKING TO THE DROP—Positioning the banking pin to a point where the escape wheel teeth will just clear or let off the pallet.

BARREL—The circular metal box which contains the mainspring.

BARREL, GOING—The type of mainspring barrel having teeth cut around the outside; these teeth are in mesh with the center wheel pinion. This driving action furnishes the motive power for the watch.

BARREL HOOK—A bent pin in the barrel to which the mainspring is attached.

BARREL RATCHET—A wheel on the barrel arbor which is prevented by a dog from turning backward while the mainspring is being wound and which becomes the base against whose resistance the train is driven.

BEARING, JEWEL—A metal support inlaid with specially formed small ruby, sapphire, or diamond to minimize the friction of a pivot or pin.

BEAT—One vibration of the balance and balance spring resulting from an impulse received by means of an escapement. (See In beat.)

BEZEL—The grooved metal ring which holds in place the crystal or glass of a watch or clock.

BRIDGE—One of the upper plates used for the support of the wheels; the central part is cut away to provide space for one or more pivot bearings.

BURNISHED PIVOT—Highly polished end of a rotating arbor.

BURR—A small piece of metal projecting from a part, such as that left on a new wheel by a gear cutter or caused by wear between gear teeth.

CANNON PINION—The pinion with a long pipe to which the minute hand is fixed.

CAPPED JEWEL—A jewel having a protective endstone.

CENTER STAFF—The arbor attached to the center wheel which carries the minute hand.

CENTER WHEEL—The wheel in ordinary clocks and watches placed in the center of the frame on whose arbor the minute hand is carried. It is intermediate between the barrel and the third wheel.

CHRONOMETER—Any very accurate time-keeper. Usually understood to mean a time-keeper fitted with a spring detent escapement, also with a fuse (stepped barrel) and a cylindrical balance spring.

CHUCK—A device inserted in the headstock of a lathe to hold the part in position for machining or other lathe operation.

CIRCULAR ESCAPEMENT—An escapement so constructed that the central portion of each pallet stone's impulse face stands at an equal distance from the pallet center.

CLEARANCE—The small space or distance between adjacent parts of a machine by which one part clears another. In the watch trade this space is called **ENDSHAKE**.

CLICK—A pawl or dog which fits into the teeth of the ratchet wheel and prevents it from turning backwards.

CLUTCH—A device in a stem-wind watch to shift the power from the stem to either the winding or the setting gearing.

CLUTCH LEVER—The lever which operates in a recess of the clutch and moves it into setting or winding position.

CLUTCH PINION—The pinion surrounding the square portion of the stem. Serves alternatively to wind and to set the watch.

CLUTCH WHEEL—The wheel which engages the setting mechanism or the winding mechanism.

COCK—A piece which serves the purpose of a bridge, but rests on one end and is held by one screw, as the balance cock of all watches.

COLLET—The collar installed on the balance staff of a watch to which one end of the balance spring is attached.

COMPENSATING BALANCE—A balance whose rim is made of brass and steel to correct for errors caused by temperature variation. The diameter increases or decreases in different temperatures so as to compensate to quicken or slow down the vibration for changes in temperature.

COUNTERSHAFT—An intermediate shaft which receives motion from a main shaft and transmits it to a working part. Used by watch-makers to reduce cutting speed.

CRESCENT—A circular notch in the edge of the roller table for the reception of the guard pin or horn.

CROWN—A grooved circular piece fastened to the stem used for winding the watch.

DEMAGNETIZING—The operating of removing magnetic properties from a piece of iron or other magnetized object.

DETENT—The device which halts and releases, at the proper instant, the escapement of a clock or watch.

DIAL—The graduated face of a timepiece.

DIAL FOOT—One of the small metal pillars attached to the back of the dial for the purpose of holding the dial in place.

DIAL TRAIN—A train of two wheels and two pinions that control the progress of the minute hand and the hour hand.

DIAL WHEELS—The wheels constituting the motion work of a watch.

DIAMANTINE—A fine white powder mixed with oil to a stiff paste; used for polishing watch parts.

DISCHARGING PALLET—That pallet over which a tooth of the escape wheel slides in order to leave from between the pallets.

DOUBLE ROLLER—A roller unit consisting of two metal disks; the upper and larger disk supports the roller jewel and is called the impulse roller; the lower and smaller disk with the crescent notch serves as the safety roller.

DRAW—A force exerted by an escape wheel tooth upon the locking face of a pallet stone because of its slant, tending to bring the pallet lever against the banking pin and keep it there.

DROP—The distance a tooth of the escape wheel travels or **DROPS** when it passes from the let-off corner of a pallet stone to the locking face

of an intercepting pallet stone. Drop is also defined as the space through which an escape wheel moves without doing any work.

ENDSHAKE—Clearance or spacing between adjacent parts of a watch, or freedom of pivots to move endways. Some such freedom is necessary, since there is no force to spare in a watch and too tight a fit would stop the movement.

END STONE—A small disk of jewel upon which a watch pivot rests. (Often called a cap jewel.) It is found only in the escapement.

ELINVAR—A non-rusting, non-magnetizable alloy containing iron, nickel, chromium, tungsten, silicon, and carbon. Used for balance and balance springs.

ESCAPEMENT—That part of the watch movement which controls the rate of running. It regulates the motion of the train thus distributing the power of the main-spring. It communicates the motive power to the balance.

ESCAPE COCK—The bracket which supports the upper ends of the escape wheel and pallet staff arbors.

ESCAPE PINION—The pinion on the escape wheel arbor.

ESCAPE WHEEL—The last wheel of a train; it gives impulse to the balance, indirectly. Easily identified by its teeth, which resemble those of a circular saw. The escape wheel moves forward one tooth at a time.

FORK—The part located at the end of the pallet lever, containing the slot which the roller jewel enters. The fork delivers the impulse to the roller jewel.

FORK HORN—(See **GUARD PIN**.)

FORK SLOT—A notch cut into the fork for the reception of the roller jewel.

FORK TOOL—A thin metal rod used to hold the balance wheel while making certain adjustments.

FRICTION JEWEL—A jewel bushing in a watch movement which has been forced into place by pressure and stays there under friction alone. (Friction jewels do not have bezels. See jewel.)

FOURTH WHEEL—The wheel in a watch that drives the escape pinion and to which arbor the seconds hand is attached.

GAGE—A measuring instrument or device.

GOING BARREL—(See **BARREL**, **GOING**.)

GRAVER—A specially sharpened steel tool used with a lathe for a variety of cutting operations.

GRAVITY—The pull of earthly bodies towards the center of the earth.

GUARD PIN—The small brass pin working in and out of the crescent to preserve the safety action by assuring that the pallet will be in its proper position, ready to receive the jewel pin on its return trip. (Also called fork horn.)

GIMBAL—A contrivance resembling a universal joint permitting a suspended object to tip freely in all directions. Marine chronometers are supported in their cases by gimbals.

HAIRSPRING—(Also called balance spring.) A fine coiled wire, one end of which is attached by a collet to the balance staff and the other end to a stationary part of the watch called a stud. This spring assists the balance to vibrate and governs its time of vibration.

HAIRSPRING TRUING—Revolving the balance and inspecting the hairspring and, if necessary, bending the coils back in original position.

HANDS—The revolving pointers which indicate the hours, minutes, and seconds.

HEADSTOCK—The portion of the lathe which receives the power and which holds and rotates the work.

HEAVY POINT—The point on the rim of an out-of-poise balance wheel where the force of gravity appears to be centered when the watch is operating in the vertical position.

HORNS—The circular sides of the fork that lead to the fork slot. Part of the safety action which insures the escapement continuing in action should the watch receive a shock of sufficient force to throw the lever off its banking pin during unlocking and impulse action.

IMPULSE—The push transmitted to the pallet by the escape wheel.

IMPULSE FACE—The inclined plane on end of pallet stone on which the escape wheel teeth press to produce the lift of an escapement action.

IMPULSE PIN—The jewel pin—usually a ruby—on the table roller of the lever escapement, which, playing into the fork of the lever, transmits the impulse to the balance.

IN BEAT—A watch is said to be in beat when the same amount of power is required to start the balance in one direction as in the other. That is, there is no tension exerted by the balance spring to either side when the escapement is at dead center.

INDIA STONE—An artificially produced stone used for sharpening tools. Softer than the Arkansas stone.

ISOCHRONISM—The property of a balance spring that allows it to move through long and

short arcs of motion in equal time; i.e., all its vibrations, of whatever length, are made in time periods exactly equal.

JEWEL—A precious stone which is pierced to receive the pivot. Jewels are used as bushings at the ends of pivots and in other places which sustain much wear. They

1. Provide smooth bearings for the pivots.
2. Obviate corrosion.
3. Reduce the wear from abrasion.

Sapphire is the best of the jewels in use; ruby is second.

JEWEL GAGE—A needle-shaped instrument provided with a scale for measuring jewel sizes.

JEWEL PIN—(Also called roller jewel.) A long, thin jewel, usually of ruby or sapphire, suspended perpendicularly in the roller. The jewel pin is the connecting link between the pallet and the balance wheel.

JEWEL PIN SHAKE—The clearance between the jewel pin and the horns of the fork when the pin is passing out of the fork slot at the time of the "drop."

LEAVES—The teeth of pinions.

LET-OFF CORNER—The extreme tip of the pallet stone where each successive tooth of the escape wheel loses contact with the pallet stone.

LEVER—In watchmaking, a metal piece to which the pallet arms are attached, and which serves to carry the impulse to the pallet from the escape wheel.

LEVER ESCAPEMENT—A watch escapement that delivers an impulse to the balance by means of two pallet stones and a lever. The extremity of the lever has a forked slot that acts directly on a roller jewel which is attached to the balance.

LIFT—The action which takes place when the impulse face of the escape wheel tooth engages the impulse face of the pallet stone or jewel.

LOCK—The amount of overlap between the pallet stone and an escape wheel tooth.

LOCKING FACE—That side of a pallet stone which locks or overlaps the tooth of an escape wheel (upon which the teeth of the escape wheel drop).

LOUPE—Also called eye lens; a piece of glass or other transparent material whose surfaces are ground to form an image by changing the direction of light rays, resulting in magnification of an object viewed through this lens.

MAINSRING—A long ribbon of steel that supplies the power for driving a clock or watch. It is coiled into the circular metal box of the

barrel with the outer end fastened to the barrel and the inner end to the barrel arbor.

MAINSRING ASSEMBLY—The barrel, mainspring, and arbor combination.

MAIN TRAIN—The toothed wheels that connect the barrel with the escapement, causing the minute hand wheel to make one turn while the escapement makes a required number of beats.

MEAN-TIME SCREWS—Screws used to bring a watch to time, sometimes called timing screws.

MICROMETER CALIPER—A precision measuring device for determining diameters and thicknesses. The metric-calibrated type is usually used in watch repairing.

MIDDLE - TEMPERATURE ERROR—The temperature error between the extremes of heat and cold—an error characteristic of a compensating balance and steel balance spring, because the compensation balance does not exactly meet the temperature error. The rim expands too much with decrease of temperature and contracts too little with the increase. Hence, a timepiece can be correctly adjusted for two points only. The unavoidable error between is the middle temperature error.

MINUTE—The sixtieth part of a mean solar (sun) hour.

MINUTE HAND—Hand of a clock or watch which indicates the minutes. (First con-centered with the hour hand in 1673.)

MINUTE WHEEL—The wheel which carries the minute hand and is driven by the cannon pinion.

MINUTE WHEEL PINION—The pinion on which the minute wheel is mounted and which drives the hour wheel.

MOTION—The amount of the circular movement of the balance wheel when oscillating. A motion of about $1 \frac{1}{8}$ + turns is considered to be the most desirable.

MOTION WORK—The wheels in a watch which make the motion of the hour hand one-twelfth as rapid as that of the minute hand.

MOVEMENT—The watch or clock complete, without dial or case—the mechanism of the watch or clock.

NEEDLE GAGE—A measuring device consisting of a narrow scale calibrated to read the diameter of a jewel placed on its needle and pushed up into the gage.

OIL RESERVOIR—The spherical space around the pivot hole in a watch jewel where oil is stored to keep the watch lubricated.

OUT-OF-POISE—The watchmakers' term for describing a balance wheel or balance wheel assembly which is not balanced.

OVER BANKING—Pushing of the ruby pin past the lever, caused by excessive variation of the balance.

OVERCOIL—The outermost coil of a Brequet hairspring, which is carried up and over the rest of the spring.

PALLET—The metal body attached to or a part of the lever. The term includes the pallet arms and pallet stones. The pallet transmits the impulse from the escape wheel to the balance.

PALLET ARBOR—The axle on which the pallet oscillates.

PALLET ARMS—The metal body which contains the pallet stones.

PALLET STAFF—The axis of the pallet or arbor upon which it is mounted.

PALLET STONE—That part of an escapement which transmits the impulse from the escape wheel to the balance. Also defined as the jewel on the contact face of the pallet where it is struck by the teeth of the escape wheel.

PAWL—Another name for a dog, click, or ratchet.

PEGGING—The operation of using a sharpened stick of pegwood to clean or polish watch parts.

PILLAR—One of the three or four short brass posts which keep the plates at their proper distance apart.

PILLAR PLATE—The lower plate of a watch movement, nearest the dial.

PINION—The smaller of two toothed wheels which are geared into one another. The larger one is called the wheel.

PIVOT—The end of an axle or arbor which rests in a support.

PLATE—Disks of brass which form the foundation of the movement. The lower plate lies next to the dial. The upper pieces supporting one, two, or three wheels are usually referred to as bridges.

POISING—Adjusting the balance wheel so that its mass is distributed equally around the axis of rotation and the effect of the force of gravity is eliminated.

PUNCH, RIVETING—The flat-faced tool for flattening the riveting shoulder of a rivet-type staff.

PUNCH, SEATING—The tool used with the staking tool to spread the riveting shoulder

when staking a balance wheel onto a rivet-type staff.

RATCHET—The pawl, or dog, which engages in the teeth of a ratchet wheel and prevents it from turning backward. It is held lightly against the periphery of the ratchet wheel by a small spring known as the ratchet spring.

RATCHET WHEEL—A wheel with triangular teeth fastened to the barrel arbor to prevent the mainspring from slipping back when it is being wound.

RATE (OF A WATCH)—The interval of time which a watch gains or loses in a given length of time, usually 24 hours.

REAMER—A small rotating finishing tool with cutting edges for enlarging or shaping a hole.

RECEIVING PALLET—That pallet stone over which a tooth of the escape wheel slides in order to enter between the pallet stones.

REGULATOR—The lever in a watch by which the pins regulating the swing of the hairspring are shifted.

REGULATOR PINS—The two small pins which embrace the hairspring and by being moved change the shape of the over coil, and, consequently, the rate of the watch.

RIM WRENCH—A small hand tool notched at the end, used for forming balance wheel rims, etc.

ROLLER—The circular plate into which the jewel pin is set in a lever escapement.

ROLLER JEWEL—(See JEWEL PIN.)

ROLLER TABLE—A flat circular metal disk from which the roller jewel is suspended.

SECONDS HAND—The hand on the dial of a clock or watch which revolves once a minute. Sometimes small and set in a small circle of its own. Sometimes long and traversing the whole dial.

SECONDS PIVOT—The prolongation of the fourth wheel arbor to which the seconds hand of a watch is fixed.

SHAKE—The space separating the letting-off corner of the pallet from the heel of an escape wheel tooth when the opposite pallet is locked at the lowest locking corner.

SIDESHAKES—Freedom of pivots to move sideways. (See endshake.)

SLIDE—The distance the pallet stone slides on the escape wheel after the balance is moved from the position in which the jewel pin shake is tried.

STAKING TOOL—An anvil-type tool used with punches to fasten watch parts together,

and to separate parts by exerting pressure at strategic points.

STEM—The winding arbor of a watch.

STUD—A small piece of metal pierced to receive the outer coil of the balance spring (hairspring).

STUMP—The small metal support used to hold a balance staff in position on the staking stand while the setting punch presses a balance arm down onto it.

TAILSTOCK—That portion of the lathe which was originated to support one end of the work, but now is used largely as a tool carrier (in horology).

T-REST—A support for steadying a graver while cutting on a jeweler's lathe.

THIRD WHEEL—The wheel in the train between the center wheel and the fourth wheel; it drives the fourth pinion.

TIMING SCREWS—Screws used to bring a watch to time, sometimes called mean-time screws.

TIMING WASHERS—Small washers punched out of extremely thin metal or foil, for use in poising balance wheels.

TRAIN—A series of two or more wheels and pinions, geared together and transmitting power from one part of a mechanism to another.

TRIPPING—The running past the pallet's locking face of an escape wheel tooth.

TRUING-IN-THE-FLAT—The operation of bending the rim of a balance wheel until (1) all parts of the rim lie in the same plane, and (2) the entire rim is perpendicular to the staff axis.

TRUING-IN-THE-ROUND—The operation of bending the rim of a balance wheel until it is concentric with the staff axis.

TURNING—A shaping or forming operation by use of the lathe.

UNDERCUTTING—Removing metal from the undersides of balance screws in the truing operation.

VERNIER CALIPER—A form of slide gage graduated in millimeters widely used by watch repairman. (This gage is also known as the Boley slide gage.)

WATCH ADJUSTING—The procedures employed in producing a uniform rate within well defined limits and under various conditions. Watch adjusting is divided into three branches: (1) position adjusting, (2) isochronal adjusting, and (3) temperature adjusting.

OFFICE MACHINES

BASKET SHIFT—When the shift key is depressed and released the segment and typebars of this type of machine move up and down.

BELL CRANK—A right angle lever for communicating motion as from one bell wire to another lying at right angles to it.

CARRIAGE SHIFT—When the shift key is depressed and released, the carriage of this type of machine moves up and down.

CYLINDER—(See platen.)

DROP (ROYAL)—The distance the carriage travels horizontally when, after a character has been printed, the machine backspaced one space, the space bar is depressed, and the same character printed again.

ECCENTRIC—A part whose axis is not centered with that of another part.

ESCAPEMENT—The mechanism which controls the movement of the carriage.

FULCRUM—The support or point of rest on which a lever turns.

KSM—Key set margin.

KST—Key set tabulator.

LOWER CASE—Print in small letters (not capitals).

MOTION—The alining on a horizontal line of the bottom of the upper case characters with the bottom of the lower case characters.

ON FEET—The adjustment made to cause the type face to print evenly with its top, bottom, and both sides.

OVERBANKING—The condition where the carriage moves one or more spaces past the position set by the margin stop.

PLATEN—The rubber covered cylinder or roller of a typewriter.

UPPER CASE—Print in capital letters.

UNDERBANKING—The condition where the carriage moves one or more spaces short of the position set by the margin stop.

GAGES AND METERS

ABSOLUTE PRESSURE—It is the total pressure exerted with respect to a perfect vacuum of zero pressure.

ACCURACY—An instrument's ability to indicate or record a true value being measured (static).

ADJUSTMENT—To change the physical characteristics of an instrument to make it more accurate.

AMBIENT—Surrounding, environmental (for example, ambient temperature refers to the temperature surrounding an instrument).

AMMETER—An instrument for measuring electric current (in amperes).

AMMETER, SPLIT CORE—A portable current-measuring instrument which uses the magnetic field around a current-carrying conductor to produce a deflection of an indicating pointer.

AMPERE—The unit of quantity of electric current, being that produced by one volt acting through a resistance of one ohm. (Named after A.M. Ampere famous French physicist.)

ATMOSPHERE—A unit of measure equal to 14.696 psi or 29.92 inches of mercury (i.e., one atmosphere = 14.696 psi).

ATMOSPHERIC PRESSURE—The pressure exerted by the atmosphere at any given point or location.

BAFFLE—A plate, wall, or screen used to deflect, check, or otherwise regulate the flow of a gas, liquid, sound waves, etc.

BAROMETER—An instrument for determining atmospheric pressure and hence for judging probable changes of weather.

BATTERY (ELECTRIC)—A cell or combination of cells, which generates electrical current by chemical action.

BOURDON TUBE—A thin-walled oval-shaped tube bent into the form of a C, which tends to straighten out when pressure is exerted in the tube. As the tube straightens, it is made to move a pointer around a dial.

BURETTE—A graduated glass tube, usually with a small opening and stopcock, for delivering measured quantities of liquid or for measuring the liquid or gas received or discharged.

CALIBRATION—(1) The operation of making an adjustment or marking a scale so that the readings of an instrument conform to an accepted standard. (2) The checking of readings by comparison with an accepted standard.

CANTILEVER ARM—A projecting beam or member supported only at one end.

CAPILLARY ATTRACTION—The action by which the surface of a liquid which is in contact with a solid is elevated or depressed.

CENTIGRADE—On the centigrade thermometer, the interval between the freezing point and the boiling point of water is divided into 100 parts or degrees, so that 0°C. corresponds to 32°F., and 100°C. to 212°F.

CENTRIFUGAL FORCE—That force which tends to drive a thing or parts of a thing, outward from a center of rotation.

CO₂ INDICATOR—An instrument designed to reveal the presence of carbon dioxide.

COMPARATOR—An instrument or machine for comparing anything to be measured with a standard instrument. Specifically, a self-contained portable pneumatic comparison-type pressure gage tester.

CONDENSATE—The product of condensation (the process of reducing from one form to another and denser form, as steam to water).

CONDUCTIVITY—The quality or power of conducting or transmitting heat, electricity, etc.

CONTROL SPRING—A small spring soldered onto the rotating mechanism of electrical meters (usually one at the top and one at the bottom of the shaft) to control and regulate the movement of the pointer.

CYCLE—When the voltage in an alternating current increases from zero to a maximum point, then decreases through zero to a maximum point in the opposite direction, then returns to zero again, a cycle is said to have been completed.

DAMPING DEVICE (ELECTRICAL)—A small metal disk mounted on the shaft of a moving element which turns between the poles of a permanent magnet. This motion sets up currents in the disk which oppose the motion of the moving magnet, resulting in a DRAG on the disk tending to stop it.

DEADWEIGHT TESTER—A hydraulic-balance type gage tester operating on the principle of subjecting the gage under test to a hydrostatic pressure created by applying weights to a piston of known area. The weighted piston applies pressure to a fluid, such as oil, in the cylinder which in turn is transmitted to the gage through a system of piping.

DIAPHRAGM POINTER GAGE—A pressure or vacuum gage containing a thin disk or membrane, whose indicating pointer moves in accord with the vibrations of the disk or membrane.

DIFFERENTIAL EXPANSION—The property of some metals or other solids to expand at different rates when heated. (See expansion coefficient.)

DIFFERENTIAL PRESSURE—The difference between two pressures measured with respect to a common basis.

DIFFERENTIAL PRESSURE GAGE—A Bourdon-type gage equipped with two Bourdon tubes so arranged as to measure the difference in

pressure between two pressure lines. Bellows gages also measure differential pressure.

ELECTRICAL RESISTANCE—The opposition offered by a substance or body to the passage through it of an electric current or magnet flux.

ELECTRODE—Either terminal of an electric source. An electrode may be a wire, a plate or other electricity-conducting object.

ELECTROMOTIVE FORCE—That which moves, or tends to move, electricity.

EXPANSION COEFFICIENT—The ratio of the increase of length, area, or volume of a body for a given rise in temperature to the original length, area, or volume. Also called coefficient of expansion.

FAHRENHEIT—On the Fahrenheit thermometer, under standard atmospheric pressure, the boiling point of water is at 212° F. and the freezing point at 32° F. above the zero of its scale.

FILAMENT—A threadlike conductor, as of carbon or metal, that is made incandescent by the passage of an electric current.

FREQUENCY—The number of cycles (as in an alternating electrical current) completed per second is called the frequency.

GAGE PRESSURE—A special case of differential pressure; positive gage pressure is the difference between absolute pressure and atmospheric pressure.

GALVANOMETER—An instrument for measuring a small electric current, or for detecting its presence or direction by means of the movements of a magnetic needle, or of a coil in a magnetic field.

GOVERNOR—An automatic attachment to an engine, compressor, etc., for controlling its speed.

HELIX—Anything having a spiral shape. (Mathematically, a helix is the shape of the curve formed on any cylinder by a straight line in a plane that is wrapped around the cylinder, such as an ordinary screw thread.)

HEXANE—A colorless, explosive gas of the petroleum series.

HYDRAULIC—Conveying, acting, or operating by water (or some other liquid).

HUMIDIFIER—A baffled water container having a gastight dividing wall; gas and air pass over the water surfaces and become moistened.

HYDRAULIC RAM—The plunger of a hydrostatic press.

HYDROSTATIC—The branch of physics which relates to the pressure and equilibrium of liquids.

HYSTERESIS—The inability of an elastic member to return to its original position after it has been stressed.

INDUCTION (ELECTRICAL)—The process by which (1) an electrical conductor becomes electrified when near a charged body, or (2) a magnetizable body becomes magnetized when in a magnetic field, or (3) an electricity moving force is produced in a circuit by varying the magnetic field linked with the circuit.

INERT GAS—A gas which has no active chemical properties.

KEEPER—In the electrical trade, a piece of steel or soft iron used to connect the poles of a magnet to preserve the intensity of the magnetization.

KILOWATT—A unit of electrical power, equal to 1,000 watts. (A watt is a unit of power equal to the rate of work represented by a current of one ampere under a pressure of 1 volt.)

LINEARITY—The closeness of a calibration curve to a straight line.

LEVELOMETER—A gage which operates on the hydrostatic principle, employing a dial-type indicator, to measure the contents of tanks.

LIQUIDOMETER—A float-actuated, remote-reading gage operating on the balanced hydraulic principle to measure the contents of tanks.

MAGNETO—An electrical device with permanent magnets, used to generate the current for the electric ignition of internal-combustion engines, etc.

MENISCUS—The curved upper surface of a liquid column; concave when the containing walls are wetted by the liquid (as with water), and convex when not (as with mercury).

MANOMETER—A gage for measuring the pressure of gases and vapors.

OHM—The unit of electrical resistance, being the resistance of an electrical circuit in which an electrical pressure of 1 volt produces a current of 1 ampere.

PARALLAX—The phenomenon responsible for errors in reading when the eye is not directly in line with a pointer whose tip is not on the same plane as the instrument's scale.

PNEUMERCATOR—A hydrostatic-type tank level indicator, operating on the principle of balancing a head of liquid in a tank against a column of mercury or other indicating medium enclosed in a gage.

POLARITY (ELECTRICAL)—The particular state (positive or negative) of a body with reference to the two poles.

POWER FACTOR—The ratio of the apparent power in an electrical circuit to the true power, expressed in percent. In direct-current circuits the power factor is always 1; in alternating current circuits it is usually less than 1. (For a detailed explanation of power factor, see page 218 of Basic Electricity, NavPers 10086-B).

PRESSURE—Pressure is force per unit of area, usually expressed as psi.

PRESSURE DIFFERENTIAL—A difference in pressure.

P. S. I.—Abbreviation for pounds per square inch.

PYROMETER—An instrument for measuring temperatures, particularly those beyond the range of mercurial thermometers, as by means of the change of electric resistance, the production of a thermoelectric current, the expansion of gases, etc.

RANGE—The range of an instrument is given by the low and high points on its scale between which continuous indication is obtained.

REPEATABILITY—The degree of closeness to which an instrument indicates the values of a variable when the conditions are repeated.

RESISTOR—A device possessing the property of electrical resistance, used in an electric circuit for protection operation or control.

RESOLUTION—The operator's ability to interpret an instrument reading.

SALINITY INDICATOR—An indicating gage which measures the approximate salt content of fresh water. It operates on the principle that the electrical conductivity of water varies with its chemical impurity content.

SENSING ELEMENT OR SENSOR—The part of an instrument which first takes energy from the measured medium to produce a condition representing the value of the measured variable.

SENSITIVITY—The smallest change in the value of a variable being measured, to which the instrument will respond.

SPAN—The difference between the lowest and highest points on the instrument's scale; lowest subtracted from highest.

STATIC CHARGE—A stationary charge of electricity, such as that produced by rubbing together unlike bodies, as amber and cloth, a glass rod and silk, etc.

STATIC FRICTION—The resistance to relative motion of two bodies in contact.

TACHOMETER—A speed counter.

TANK LEVEL INDICATOR—A hydrostatic-type tank gage, usually operating on the principle of balancing a head of liquid in a tank against a column of mercury, or on the balanced hydraulic principle employing a float-actuated remote reading dial gage. (See Levelometer, Liquidometer, and Pneumercator.)

TERMINAL (ELECTRICAL)—A device attached to the end of a wire or cable or apparatus for convenience in making electrical connections.

TEST INSTRUMENT—The instrument being tested.

THERMAL ALARM—A temperature alarm signal device, used on Navy ships to give warning of excessive superheater temperatures. A light, a horn, or both types of warning may be employed.

THERMOCOUPLE PYROMETER—A temperature measuring instrument using the change of electric resistance of a conductor when heated to indicate the temperature being measured.

THERMOELECTRIC—Of or pertaining to electricity produced by the direct action of heat, as by the unequal heating of a circuit composed of two dissimilar metals.

TORQUE—That which produces or tends to produce rotation.

VACUUM—A special case of differential pressure. Positive vacuum is the difference between atmospheric pressure and absolute pressure usually measured in inches or millimeters of mercury.

VAPOR INDICATOR—An electrochemical device used to detect the presence of explosive or flammable mixtures.

VISCOSITY—The ability of a liquid to cling, or resist flowing.

VOLT—The unit of electromotive force, defined as the force which steadily applied to a circuit whose resistance is one ohm will produce a current of one ampere.

VOLTAGE—The electric potential difference, expressed in volts.

VOLTMETER—An instrument for measuring in volts the difference of potential between different points of an electrical circuit.

WATT—The unit of electric power, equal to the rate of work represented by a current of one ampere under a pressure of one volt.

WATTMETER—An instrument for measuring electric power in watts.

WATT-HOUR METER—A device used to record electric energy, usually in kilowatt hours.

WHEATSTONE BRIDGE—A device for the measurement of electrical resistance, invented by Sir Charles Wheatstone, English physicist.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1971-483-612/5

